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# Synopses of Federal Demonstrations of Innovative Site Remediation Technologies

Second Edition



*Prepared by the*  
**Member Agencies of the  
Federal Remediation Technologies Roundtable**

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Prepared by the Member Agencies of the  
Federal Remediation Technologies Roundtable:

U.S. Environmental Protection Agency  
Department of Defense  
    U.S. Air Force  
    U.S. Army  
    U.S. Navy  
Department of Energy  
Department of Interior

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## **NOTICE**

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## **PREFACE**

This collection of abstracts, compiled by the Federal Remediation Technology Roundtable, describes field demonstrations of innovative technologies to treat hazardous waste. This document updates and expands information presented in the first edition of the collection which was published in 1991. Synopses appearing for the first time in this edition are denoted in the Table of Contents by an asterisk.

The collection is intended to be an information resource for hazardous waste site project managers for assessing the availability and viability of innovative technologies for treating contaminated ground water, soils, and sludge. It is also intended to assist government agencies in coordinating ongoing hazardous waste remediation technology research initiatives, particularly those sponsored by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), and the U.S. Department of Interior (DOI). Innovative technologies, for the purposes of this compendium, are defined as those technologies for which detailed performance and cost data are not readily available.

The demonstrations contained herein have all been sponsored by EPA, DOD, DOE, and DOI. In total, 91 demonstrations in six different technology categories are described. These demonstrations involve the use of innovative technologies to treat soil and ground water. A matrix listing the demonstration categories, the type of contaminant, media that can be treated, and the treatment setting for innovative technologies demonstrated is provided in Exhibit 1 on page ix. Although descriptions of demonstrations involving more conventional treatment technologies, such as incineration and solidification, do not appear in the main body of this edition, a selection of such abstracts have been included in Appendix A for your information.

This document focuses on specific demonstrations projects. However, Appendix B describes more general demonstration programs being undertaken by the Departments of Energy and Interior.

This document represents a starting point in the review of technologies available for application to hazardous waste sites. This compendium should not be looked upon as a sole source for this information — it does not represent all innovative technologies nor all technology demonstrations performed by these agencies. Only Federally sponsored studies and demonstrations that have tested innovative remedial technologies with site specific wastes under realistic conditions as a part of large pilot- or full-scale field demonstrations are included. Those studies included represent all that were provided to the Federal Remediation Technology Roundtable at the time of publication. Information collection efforts are ongoing.

### **The Federal Remediation Roundtable**

This publication was prepared under the auspices of the Federal Remediation Technologies Roundtable (Roundtable). This organization was created to establish a process for applied hazardous waste site remediation technology information exchange, to consider cooperative efforts of mutual interest, and to develop strategies and analyze remedial problems that will benefit from the application of innovative technologies. The Roundtable is comprised of representatives from several Federal agencies:

## **Environmental Protection Agency, Technology Innovation Office (EPA/TIO)**

The mission of the Technology Innovation Office (TIO) is to increase applications of innovative treatment technology by government and industry to contaminated waste sites, soils, and ground water. TIO intends to increase usage of innovative techniques by removing regulatory and institutional impediments and providing richer technology and market information to targeted audiences of Federal agencies, States, consulting engineering firms, responsible parties, technology developers, and the investment community. The scope of the mission extends to Superfund sites, corrective action sites under the Resource Conservation and Recovery Act (RCRA), and underground storage tank cleanups. By contrast, TIO is not a focus for EPA interest in treatment technologies for industrial or municipal waste streams, for recycling, or for waste minimization.

## **Environmental Protection Agency, Office of Research and Development (EPA/ORD)**

The Office of Research and Development Superfund Innovative Technology Evaluation (SITE) program supports development of technologies for assessing and treating waste from Superfund sites. The SITE program was authorized by the Superfund Amendments and Reauthorization Act of 1986 with the goal of identifying technologies, other than land disposal, that are suitable for treating Superfund wastes. The program provides an opportunity for technology developers to demonstrate their technology's capability to successfully process and remediate Superfund waste. EPA evaluates the technology and provides an assessment of potential for future use for Superfund cleanup actions. The SITE program has currently evaluated or supported research efforts for about 135 innovative treatment technologies. The SITE program is administered by EPA's Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio.

## **Department of Defense (DOD), Defense Environmental Restoration Program (DERP)**

The Office of the Secretary of Defense (OSD), operating through the Deputy Assistant Secretary of Defense, Environment (DASD (E)), establishes policy and monitors the Armed Forces' execution of the DOD hazardous waste site clean-up program. The Defense Environmental Restoration Program (DERP) funds activities at over 17,000 DOD sites located on nearly 1,700 properties through the Installation Restoration Program (IRP). The DOD works cooperatively with the Environmental Protection Agency and the States toward the goal of taking timely, effective, and efficient actions at all stages of the DERP. Research and development of better methods for site investigation and cleanup is an important part of DERP. Many innovative technologies have been developed and demonstrated to improve the speed and cost-effectiveness of DOD site cleanups.

## **U.S. Air Force Civil Engineering and Support Agency (AFCESA)**

The Air Force Civil Engineering and Support Agency (AFCESA) is responsible for identifying, developing, and testing technologies that may be useful for remediating contaminated sites as part of the Air Force's Installation Remediation Program.

## **U.S. Army Corps of Engineers**

In support of the Army's Installation Restoration (IR) Program, the U.S. Army Corps of Engineers has the responsibility of ensuring the development of necessary and improved technology for conduct of the Program. The U.S. Army Corps of Engineers is also charged with the responsibility for developing improved pollution abatement and environmental control technology

in support of the U.S. Army Material Command industrial complex (Pollution Abatement or PAECT Program). The purpose of the IR Decontamination Development Program is to provide R&D support to required assessment and clean-up actions at Army installations. Efforts include evaluating commercially available state-of-the-art technologies as well as developing new, innovative technologies that are more economical and efficient than existing technology. The PAECT program addresses waste minimization and disposal alternatives for the Army's industrial operations.

#### **U.S. Army Toxic and Hazardous Materials Agency (USATHAMA)**

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), a Field Operating Activity (FOA) of the U.S. Army Corps of Engineers, is a major focal point in the program management and support efforts of the Army-wide environmental program. With its principal focus directed toward supporting the installation in achieving and maintaining environmental compliance, the Agency's activities fall into five major categories:

- Environmental Compliance;
- Installation Restoration Program (IRP);
- Environmental Training and Awareness;
- Research and Development (R & D); and
- Environmental Information Management.

#### **U.S. Navy, Naval Civil Engineering Laboratory (NCEL)**

The Naval Civil Engineering Laboratory (NCEL) develops technologies for restoration efforts at Navy and Marine Corps Installations. NCEL serves as a consultant to project managers at Navy restoration sites, planning and conducting applied research and demonstration projects to support restoration objectives.

#### **Department of Energy (DOE), Office of Environmental Restoration**

The Department of Energy (DOE) is faced with the largest environmental clean-up task ever to confront the United States. The primary objectives of DOE's Environmental Restoration (ER) Program are to stabilize radioactive waste or perform decontamination and decommissioning at contaminated DOE and legislatively authorized non-government installations and sites; conduct assessments and characterization of DOE sites to determine if there is the potential for radioactive and hazardous waste releases; and to protect human health and the environment. The goal of the Environmental Restoration Program is the cleanup of contaminated DOE and legislatively authorized sites within 30 years.

#### **Department of Energy (DOE), Office of Technology Development**

DOE's Office of Technology Development was established to identify technologies in the research and development and demonstration (RD&D) stage, and to demonstrate, test, and evaluate those technologies that will provide DOE with accelerated and/or improved methods for achieving its environmental goals as specified in its Five-Year Plan.

## **Department of Interior (DOI)**

As the principal conservator of the Nation's public lands and natural resources, the Department of Interior (DOI) has three primary areas of waste management concern: abandoned mine sites; illegal dumping on Federal lands; and landfills that were leased to counties and municipalities. DOI manages wastes to safeguard resource values and to protect the lives and health of the millions of people who work, live, and recreate on lands managed by DOI. The Bureau of Mines, the Bureau of Reclamation, and the Geological Survey are the primary agencies within DOI who provide technical consultation and research assistance to DOI and other Federal agencies for solution of waste management problems. For example, extensive research conducted by the nine research laboratories of the Bureau of Mines is directly applicable to the management of mining and mineral waste problems. This technology has been extended to encompass the cost-effective treatment of other inorganic wastes.

### **Future Demonstrations**

This publication will be updated on a periodic basis. If you will be conducting a demonstration featuring an innovative hazardous waste treatment technology in the future, or if you are aware of a project that is relevant to this collection but has been omitted, please forward this information to TIO:

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For your convenience, we have included, at the end of this volume, the Innovative Remedial Technologies Information Collection Form to guide you in formatting the information for inclusion in this compendium. The Roundtable developed this form as a model for use in collecting findings on innovative technologies and their applications, effectiveness, and costs.

The form is intended to facilitate new data collection efforts, and it indicates the data we are most interested in capturing. If, however, you have already collected and recorded the information in an alternative format, please feel free to forward any previously written abstract or summary. We will reformat it to be included in this compendium.

If you have any comments on the usefulness and clarity of this publication, please complete the suggestion form on the last page, and send it to Daniel Powell at the address listed above.

## Exhibit 1

**Matrix Showing the Various Combinations of  
Technology/Contaminant/Media/Treatment Type Addressed in this Volume**

Innovative Technology	Contaminant								Media				Treatment Setting		Page
	Halogenated volatiles and semivolatiles	Nonhalogenated volatiles and semivolatiles	PCBs	Pesticides	Cyanides	Metals	Radioactive Materials	Explosives	Surface Water	Groundwater	Soils	Sludges	In Situ	Ex Situ	
Bioremediation	✓	✓	✓			✓		✓			✓	✓	✓	✓	1
Chemical Treatment	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	51
Thermal Treatment	✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓	75
Vapor Extraction	✓	✓								✓	✓	✓	✓		103
Soil Washing	✓	✓	✓	✓	✓	✓				✓	✓	✓		✓	125
Other Physical Treatment	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	145

# **Bioremediation**





## Above-Ground Biological Treatment of Trichloroethylene Trichloroethylene (TCE) in Ground Water (In Situ Treatment)

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### Technology Description

In this treatment, methane-degrading bacteria co-metabolize short-chain, chlorinated aliphatic hydrocarbons. This technology is applicable to the removal of short chain chlorinated aliphatic hydrocarbons from water. It can be used as an above-ground "pump and treat" method for in situ remediation or the removal of similar compounds from any water stream.

An enzyme, a non-specific oxygenase that metabolizes methane, attacks trichloroethylene (TCE). The bacteria cannot, however, use TCE as "food" but must have methane as a carbon source. The reaction can take place in a bioreactor or in situ. A mixture of oxygen and methane is passed through the reactor or reaction zone to sustain the microbial population. The contaminated water is allowed to percolate down through the bed. The packing material can be soil, but care must be taken to avoid plugging.

### Technology Performance

A pilot-scale test of this treatment technology was conducted at Tinker Air Force Base, Oklahoma, during 1989. Ground Water contaminated with TCE was pumped up from a contamination site and flowed through the bioreactor. Approximately 80 percent destruction of TCE was achieved. Flow rate through the reactor was two to three L/min, with a retention time of 20 to 50 minutes in the reactor. No hazardous intermediate compounds are created with this process.

A joint effort is currently underway by the AFCEA and the DOE Oak Ridge National

Laboratory (ORNL) to perform a comparison test in the field between two bioreactors capable of biodegrading TCE within a mixture of other solvents. A reactor inoculated with a mixed methanotrophic culture will be operated alongside a bioreactor seeded with a *Pseudomonas* culture capable of degrading TCE in the presence of some aromatic compounds. The two reactors will be run side by side at the K-25 site (Oak Ridge Gaseous Diffusion Plant) at ORNL. The objectives of the study include determining which culture is most effective at biodegrading a waste mixture such as found at the K-25 site and optimizing this bioreactor process.

### Remediation Costs

Cost information is not available.

### Contact

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904/283-6036



## **Aerated Static Pile Composting Explosives (TNT, RDX, HMX) in Lagoon Sediments**

---

### **Technology Description**

Composting is a process by which organic materials are biodegraded by microorganisms, resulting in the production of organic and inorganic by-products and energy in the form of heat. This heat is trapped within the compost matrix, leading to the self-heating phenomenon known as composting. Composting is initiated by mixing biodegradable organic matter (explosives in this study), with organic carbon sources and bulking agents, which are added to enhance the porosity of the mixture to be composted.

In "static pile" composting, an aeration/heat removal system is utilized to increase process control over the composting system. The aeration/heat removal system typically takes the form of a network of perforated pipe underlying the compost pile. The pipe is attached to a mechanical blower and air is periodically drawn or forced through the compost to effect aeration and heat removal.

The composting test facilities were constructed of concrete test pads with runoff collection systems and sumps, covered by a roof to protect the compost piles from weather and to minimize the amount of moisture collected in the sump. Bulking agents and carbon sources consisted of horse manure, alfalfa, straw, fertilizer, and horse feed. Baled straw was used to contain the pile contents, and was arranged in a ring around the perimeter of each pile. Sawdust and hardwood mulch were used to construct the pile bases, provide additional bulking material, and insulate the piles. After mixing, the compost was transported to the composting pads. Each compost pile contained a system of pipes connected to a blower, as described above. A cross-sectional schematic diagram of a compost pile is provided.

### **Technology Performance**

The primary objective of this study was to evaluate the utility of aerated static pile composting as a technology for remediating soils and sediments contaminated with the explosives TNT, HMX, RDX, and tetryl.

Secondary objectives included evaluating the efficacy of thermophilic (55°C) versus mesophilic (35°C) composting, evaluating different materials handling and process control strategies, and determining transformation products when Standard Analytical Reference Materials (SARMs) were available.

Temperature was the primary test variable investigated. The temperature of one set of compost piles was kept within the mesophilic range; the temperature of the second set of piles was kept in the thermophilic range. The initial concentration of explosives in test sediments collected from the lagoon was 17,000 mg/kg. Phase I (piles 1 and 2) was conducted with a mixture of lagoon sediments, sawdust, wood chips, and a straw/manure mixture. Based on data received from phase I, phase II (piles 3 and 4) added alfalfa and horse feed to the compost mixture to increase the concentration of biodegradable organic carbon in the compost mixture. After 153 days of composting, the solvent-extractable total explosives were reduced to 376 mg/kg and 74 mg/kg in the mesophilic and thermophilic piles, respectively. The mean percent reductions of extractable TNT, RDX and HMX were 99.6, 94.8, and 86.9 weight-percent in the mesophilic piles, and 99.9, 99.1, and 95.6 weight-percent in the thermophilic piles.

The results of this field demonstration indicate that composting is a feasible technology for

decontaminating explosives-contaminated soils and sediments. Further investigation is warranted for optimizing the materials balance and soil loading rate for mixtures to be composted, minimizing bulking agent used, and developing a design and operation management plan for a full-scale composting facility. In addition, the compost residue should be subjected to a toxicity evaluation and more extensively analyzed to determine the final fates of HMX, RDX, TNT, and tetryl.

### **Remediation Costs**

Cost information is not available.

### **General Site Information**

This field-scale demonstration project was conducted at the Louisiana Army Ammunitions Plant (LAAP). Compost piles were constructed and tested at LAAP between December 1987 and April 1988. Phase I piles were tested for 33 days; phase II piles were tested for 153 days. Approximately 21 cubic yards of sediment was excavated from Pink Water Lagoon No. 4 for use in this study.

LAAP was built to load and pack ordinance for the U.S. Army. Explosives have never been manufactured at the facility, but are brought in and utilized in loading, assembling, and packing lines. Initially, the area where the field demonstration was conducted was used as a burning grounds to dispose of out-of-specification ordnance. These burning pits were converted to lagoons in the mid-1940s. The lagoons were used to dispose of wastewater generated during wash down of the munitions loading lines. Equipment used to load munitions was washed with water, and the resulting wastewater contained high concentrations of suspended explosives ("pink water"). Pink water was transported to the unlined lagoons and dumped into individual lagoons via a concrete spillway. Suspended explosives settled to the bottom of the lagoons. Over the period of approximately 30 years during which pink water was disposed of in the lagoons, high concentrations of explosives

accumulated in the upper sediment. The highest concentrations (300,000 to 600,000 mg/kg) accumulated near the spillways. In October 1984, the pink water lagoon site at LAAP was proposed for inclusion on the National Priority List (NPL).

### **Contacts**

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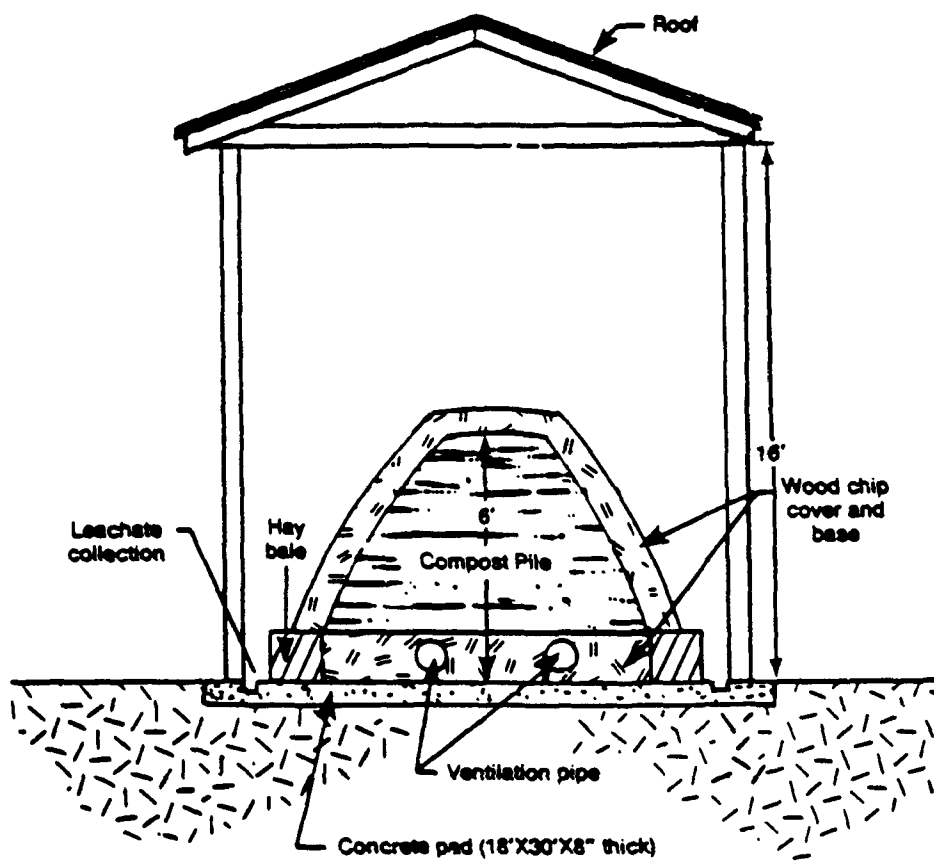
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Aerated Static Pile Composting Test Facility



## **Aerated Static Pile Composting Propellants (Nitrocellulose) in Soil and Sediments**

---

### **Technology Description**

Composting is a process by which organic materials are biodegraded by microorganisms, resulting in the production of organic and inorganic byproducts and energy in the form of heat. This heat is trapped within the compost matrix, leading to the self-heating phenomenon known as composting. Composting is initiated by mixing biodegradable organic matter (nitrocellulose (NC) in this study), with organic carbon sources and bulking agents, which are added to enhance the porosity of the mixture to be composted.

In "static pile" composting, an aeration/heat removal system is utilized to increase process control over the composting system. The aeration/heat removal system typically takes the form of a network of perforated pipe underlying the compost pile. The pipe is attached to a mechanical blower and air is periodically drawn or forced through the compost to effect aeration and heat removal. The primary objective of hazardous materials composting is to convert hazardous substances into innocuous products for ultimate disposal, such as land application.

The composting test facilities were constructed of concrete test pads with runoff collection systems and sumps, covered by a roof to protect the compost piles from weather and to minimize the amount of moisture collected in the sump. Bulking agents and carbon sources consisted of a cow manure slurry, alfalfa, straw, and horse feed. Baled straw was used to contain the pile contents, and was arranged in a ring around the perimeter of each pile. Sawdust and hardwood mulch were used to construct the pile bases, provide additional bulking material, and insulate the piles. After mixing, the compost was transported to the composting pads. Each compost pile contained a system of perforated

and non-perforated pipes connected to a blower. The blowers were used to pull air through the compost piles to promote aeration and remove excess heat. A cross-sectional schematic diagram of a compost pile is provided.

### **Technology Performance**

The primary objective of this study was to evaluate the utility of aerated static pile composting as a technology for NC fine (out-of-specification NC) remediation and destruction of soils contaminated with NC. Secondary objectives included evaluating the efficacy of thermophilic (55°C) versus mesophilic (35°C) composting, determining a maximum soil loading rate, and comparing different process control and material handling strategies.

The test variable in compost piles 1 and 2 (phase I) was temperature. The temperature of pile 1 was kept within the mesophilic range, and the temperature of pile 2 was kept in the thermophilic range. The concentration of NC in test soils collected from the dredge basin were 18,800 mg/kg for phase I tests. After mixing, total NC concentration in pile 1 was 3,670 mg/kg, and concentration in pile 2 was 3,608 mg/kg. After 152 days of the study, mean total NC concentrations were 651 mg/kg and 54 mg/kg, respectively. Information concerning the effect of temperature on the NC concentration was inconclusive, however, because there were apparent discrepancies in the starting data gathered for pile 1.

The test variable in piles 3 and 4 (phase II) was the degree of soil loading within each pile. The initial soil loading was increased from 19 percent in phase I to 22 percent in pile 3, and 32.5 percent in pile 4. The concentration of NC in tests soils collected for phase II was 17,027

mg/kg. After mixing, the concentration of NC in pile 3 was 7,907 mg/kg, and 13,086 mg/kg in pile 4. After 112 days of the study, total mean concentrations of NC were 30 mg/kg and 16 mg/kg, respectively. Both piles showed greater than 99.5 percent reduction of NC from the starting point of the test. These results suggest that successful composting will likely occur at sediment loading rates of up to 50 percent or exceeding 50 weight-percent.

The results of this field demonstration indicate that composting is a feasible technology for reducing the extractable NC concentration in contaminated soils. In addition, this study provides tentative evidence indicating that NC can be degraded when incorporated into a mixture to be composted at a high concentration.

#### **Remediation Costs**

Cost information is not available.

#### **General Site Information**

This field-scale demonstration project was conducted at the Badger Army Ammunitions Plant (BAAP) in Sauk County, Wisconsin. Four compost piles were constructed at BAAP during the period from April 1988 to January 1989. The first set of compost piles was tested

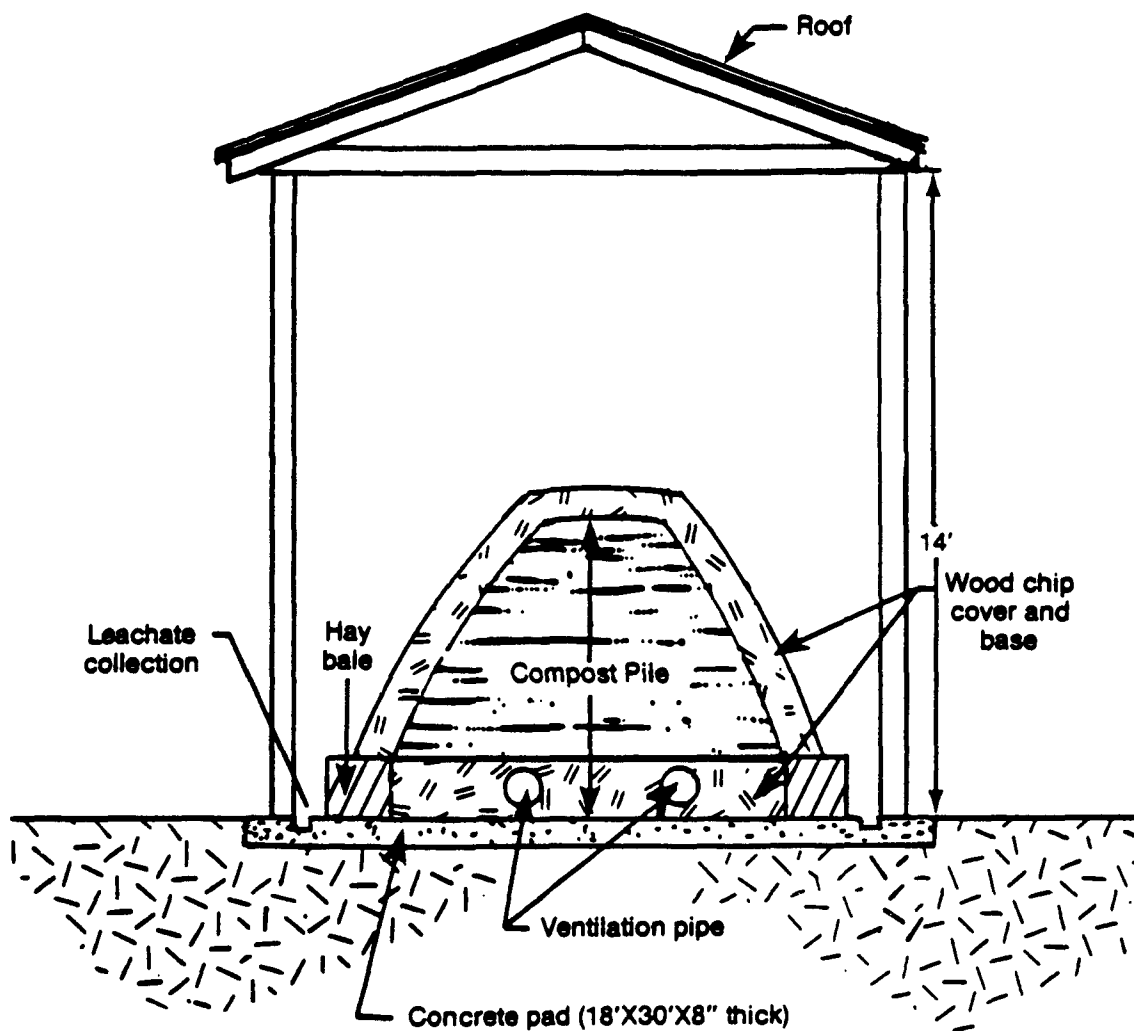
for 151 days; the second set was tested for 112 days. Approximately 13 cubic yards of test soils were excavated from Dredge Spoil Basin No. 1 for use in this study.

Constructed in 1942, the plant operated intermittently over a 33-year period, producing single- and double-base propellants for rocket, cannon, and small arms ammunition. During the plant's period of active operation, various chemical materials were produced, and the associated wastes and manufacturing byproducts were disposed on site. The wastes included acids, nitroglycerin, and nitrocellulose (NC). As a result of the disposal practices, contamination of soils, the underlying aquifer, and, to some extent, surface waters has occurred.

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Aerated Static Pile Composting Test Facility



## Aerobic Composting Optimization

### Explosives (TNT, RDX, HMX) in Contaminated Soil and Sediment

#### Technology Description

Composting is a controlled biological process by which biodegradable materials are converted by microorganisms to innocuous, stabilized by-products. In most cases, this is achieved by the use of indigenous microorganisms. Explosives-contaminated soils are excavated and mixed with bulking agents, such as wood chips, and organic amendments, such as animal, fruit, and vegetative wastes. Maximum degradation efficiency is controlled by maintaining moisture content, pH, oxygenation, temperature, and the carbon-to-nitrogen ratio. There are three process designs used in composting: aerated static piles, windrowing, and mechanically agitated in-vessel composting. This technology requires substantial space to conduct the composting operation and results in a volumetric increase in material due to the addition of amendment material.

The composting demonstration at Louisiana Army Ammunition Plant (LAAP) demonstrated that aerobic, thermophilic composting is able to reduce the concentration of explosives (TNT, RDX, and HMX) and associated toxicity to acceptable health-based clean-up levels. However, an economic analysis determined that full-scale implementation of composting of explosives-contaminated soils using previously investigated design parameters was not economically competitive with incineration. An optimization field demonstration was initiated at a National Priority List (NPL) site at Umatilla Depot Activity, Hermiston, Oregon, to investigate several process design parameters that would make this technology more cost effective. In addition, extensive chemical characterization and toxicity studies were conducted on the final composted product.

The primary objective of this study was to increase the quantity of soil processed in a composting treatment system per unit of time. Since soil throughput is dependent on the rates of degradation and the percent soil loading, the key variables investigated in the study were amendment mixture composition and percent contaminated soil loading. In addition, two technologies were evaluated: aerated static pile and mechanically agitated in-vessel composting systems.

Amendment selection was based on adiabatic testing using a combination of fifteen readily available agricultural wastes. The amendments selected and their approximate costs are provided in Table 1. Percent soil loading was investigated using seven 3-cubic-yard aerated static pile systems which were constructed from fiberglass to model actual static pile conditions. Different soil amendment ratios and amendment mixture compositions were investigated using a special 7-cubic-yard pilot-scale mechanically agitated in-vessel (MAIV) system constructed according to rigorous explosive safety standards. The MAIV system uses rotating augurs attached to the rotating cover to mix the compost.

The static pile systems and the MAIV system were housed in greenhouses to protect them from the environment and prevent the spreading of contaminated dust. A computer-based data acquisition and control system was used to monitor and regulate the environment in each of the compost systems. Temperatures were kept from exceeding 55°C using forced aeration and the moisture content was maintained at between 45 and 50 percent. Compost samples were taken at various time intervals, homogenized and split into two fractions. One fraction was analyzed for the presence of TNT, RDX, and HMX, while the other was tested for toxicity.



Since the implementation of this technology will be based on its ability to meet health-based clean-up criteria, the resultant composted material was subjected to chemical characterization and toxicological evaluation.

### **Technology Performance**

The study confirmed the LAAP composting study results which indicated that composting can effectively treat TNT-, RDX-, and HMX-contaminated matrices. The study indicated that both static pile and MAIV composting technological approaches are effective in degrading explosives. The percent reduction of explosives observed in the tests are provided in Table 2. Other major findings include the following:

- In the static pile tests, the majority of the degradation occurred in the first 44 days, while the majority of the degradation occurred in the first 10 days in the MAIV tests;
- The amendment composition is an important parameter in achieving maximum reduction of RDX and HMX; the maximum loading level for both appears to be 30 volume percent;
- Mixing is important in achieving rapid and extensive destruction of explosives (A pilot-scale composting windrow demonstration has been initiated as a result of this finding and is scheduled for completion in FY92);
- Chemical characterization and toxicity testing concluded that composting can effectively reduce the concentrations of explosives and bacterial mutagenicity in contaminated soil and can reduce the aquatic toxicity of leachate compounds.

Additional studies are being sponsored to determine the long-term effectiveness of composting and the nature of the binding of the biotransformation products.

### **Remediation Costs**

Costs will vary with the amount of soil to be treated, availability of amendments, type of process design employed, and time allowed to remediate the site. Costs for composting 8,000 tons of explosives-contaminated soils are estimated to be 50 percent less expensive than incinerating the same amount of soil.

### **General Site Information**

Umatilla Depot Activity in Hermiston, Oregon, was selected as the site for this demonstration. Between 1950 and 1965, it was the site of a facility for recovering explosives from unserviceable munitions. The process resulted in large quantities of explosives-contaminated water which was discharged into unlined settling basins. These washout lagoons were placed on the NPL in 1987 because of the presence of explosives in the water table aquifer. Hand-excavated soils from these lagoons were used in this demonstration.

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Table 1. UMDA Amendment Composition and Approximate Cost			
Amendment	Mix		
A	B	C	
Sawdust	30%		22%
Apple pomace	15%		6%
Chicken manure	20%		
Chopped potato	35%		17%
Horse manure/straw		50%	
Buffalo manure		10%	
Alfalfa		32%	22%
Horse feed		8%	
Cow manure			33%
Cost per ton	\$15	\$200	\$11

Table 2. Percent Reduction of Explosives				
Test (%soil)	Amendment Mix	Percent Reduction		
		TNT	RDX	HMX
Static Pile:				
0% (Control)	A	n/a	n/a	n/a
7%	A	91	73	39
10%	A	96	46	21
10%	C	99	93	80
20%	A	94	16	5
30%	A	98	22	11
40%	A	79	0	2
Mechanical:				
10%	A	97	90	29
10%	B	99	99	95
25%	C	99	97	68
40%	C	97	18	0

n/a — Uncontaminated soil, no explosives present



## **Biodecontamination of Fuel Oil Spills**

### **Fuel Oil in Soil (In Situ Treatment)**

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#### **Technology Description**

In this treatment, biodegradation is accomplished by applying special oil-degrading bacteria to a bioreactor while filling the reactor with leachate water. As the reactor overflows from a secondary clarifier, bacteria are carried to a spray field sump and to injection wells. Surface sprayers apply the treated leachate water on the spray field while the injection wells apply the treated leachate water to oil spill-contaminated soil under the buildings. As more water is added to the system and the ground under the buildings, the contaminated area becomes saturated. Run-off water along with leachate water is collected in a trench down-slope from the contaminated area. The collected water is pumped back to the aerated bioreactor where bacterial growth on the high surface area matrix, on which some of the bacteria are immobilized, occurs. Nutrient and detergent are added to the oxygen-enriched treated leachate water along with bacteria, and it is recirculated to the spray field and injection wells.

#### **Technology Performance**

The microorganisms function best at temperatures between 20°C and 35°C.

#### **Remediation Costs**

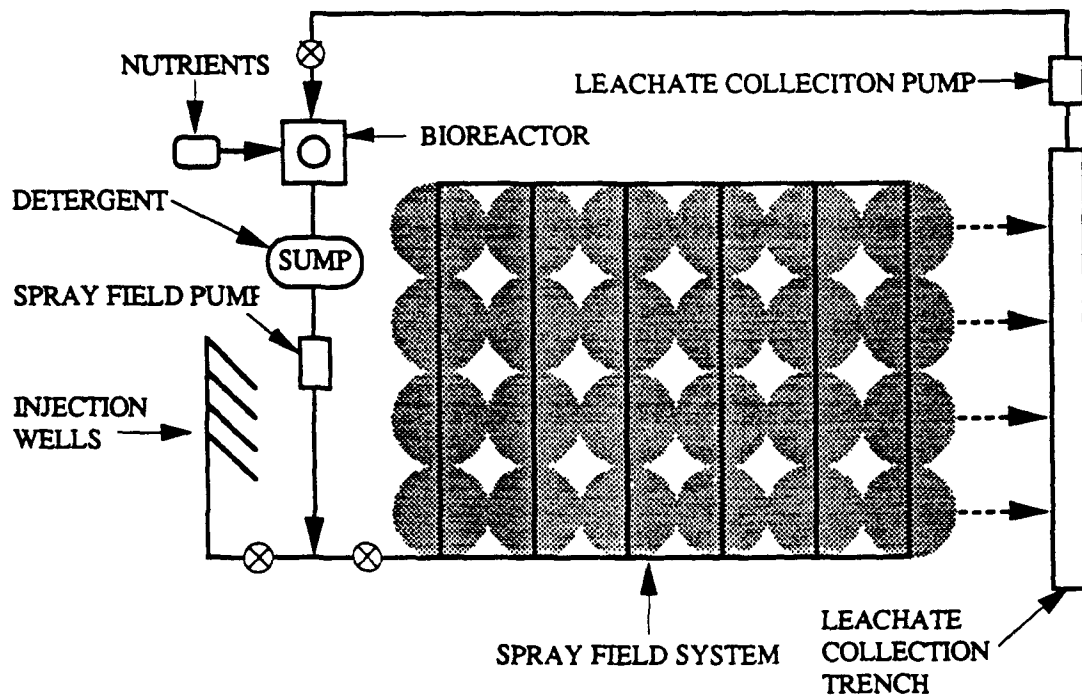
The site was cleaned to a satisfactory level for approximately \$37,000, not including shipping the equipment to the site, installation labor supplied by facility personnel, and analytical costs.

#### **General Site Information**

This method was implemented to clean up a fuel oil spill resulting from leaking pipes which connected to #2 diesel fuel storage tanks at a Naval Communication Station at Thurso, Scotland. The contaminated area had a considerable slope, and the contaminated soil was a thin layer over a relatively impermeable rock substrate. In this case, oil was entrapped in the soil matrix beneath boiler and power buildings, an area approximately 800 m<sup>2</sup>. The project lasted from February to October 1985.

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Biodecontamination Process



## **Biodegradation**

### **TCE in Soil and Ground Water (In Situ Treatment)**

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#### **Technology Description**

This biodegradation process has two phases: (1) use of pump and treat bioreactors to degrade trichloroethylene (TCE) and polychloroethylene (PCE) in ground water and (2) use of vegetation to encourage a rhizosphere that can degrade TCE and PCE in surface soil. The first phase has three parts: isolating microbes from TCE-contaminated soil that are capable of degrading TCE and PCE in water; optimizing the degradation capabilities of these microbes in laboratory bioreactors; and building and testing a pilot-scale (10 gpm) bioreactor at C&P Burning Rubble Pits.

One benefit from this task is that large-scale bioreactors can be used in various pump and treat scenarios of ground water to remove both TCE and other volatile and non-volatile organics. Another benefit from this task is that whenever organic chemicals contaminate surface soils, selective vegetation and cultivation techniques can be used to remediate the site in a very aesthetic and cost-effective manner.

#### **Technology Performance**

This process was recently tested at DOE's Savannah River site. The results from the first task were positive:

- Bacteria that can aerobically degrade TCE was isolated from native soil;
- Propane or methane was found to stimulate TCE degradation more than several other electron donors;
- Fluidized expanded bed bioreactors, using propane or methane as a primary energy source, were 99 percent and 50 percent

effective in reducing TCE concentrations in water, respectively; and

- Other wastes were also degraded when mixed wastes were used in the reactor.

The results from the second task were also positive:

- Vegetated soil was demonstrated to oxidize TCE-contaminated soil faster than un-vegetated soil or sterilized soil at the Miscellaneous Chemical Basin;
- Vegetation analysis showed no difference with normal vegetation succession for the area;
- Four of the dominant plants at the test site were compared and found to have significantly different abilities to encourage TCE degradation; and
- Phospholipid fatty acid analysis of the rhizosphere defined the physiological state of rhizosphere microbes.

#### **Remediation Costs**

Cost information is not available.

#### **General Site Information**

Biodegradation technology was tested at Savannah River Site, Miscellaneous Chemical Basin, and C&P Burning Rubble Pits to remove TCE from soil and ground water.

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## **Biodegradation of Lube Oil- Contaminated Soils Motor Oil in Soil (In Situ Treatment)**

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### **Technology Description**

This treatment process requires the addition of inoculant and nutrients to the contaminated soils during disking. (The nutrients in the pilot studies have consisted of sodium acetate, minerals — potassium, magnesium, ammonium, phosphate, and sulfate ions — and Tween 80, a surfactant.) Afterward, the site is covered with plastic sheeting. The plastic sheeting must have holes to allow the transport of air.

This method is applicable for oil spills at maintenance facilities, air strips, along roadways and streets, and parking lots. Although research on the method has been directed to degradation of used lubrication oil, it should be applicable to almost any non-functionalized aliphatic hydrocarbon.

### **Technology Performance**

A small-scale pilot test has been conducted at the U.S. Army Construction Engineering Research Laboratory in Champaign, Illinois. Noticeable reduction in contaminant concentrations were

evident after four to six weeks. Pilot plots consisted of plastic tubs containing eight kilograms of contaminated soil placed outside and covered with plastic. Flask tests were conducted initially to identify optimum conditions.

### **Remediation Costs**

Cost information is not available.

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## **BIO-FIX BEADS**

### **Metals in Water**

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#### **Technology Description**

Porous polymeric beads containing immobilized biological materials have been developed to extract toxic metals from water. The beads, designated as BIO-FIX beads, are prepared by blending biomass such as sphagnum peat moss or algae into a polymer solution and spraying the mixture into water. The beads have distinct advantages over traditional methods of utilizing biological materials in that they have excellent handling characteristics and can be used in conventional processing equipment or low-maintenance systems. Cadmium, lead, and mercury are a few of the many metals readily removed by BIO-FIX beads from acid mine drainage (AMD) waters, metallurgical and chemical industry wastewaters, and contaminated ground waters. Because of their affinity for metal ions at very low concentrations, National Drinking Water Standards and other discharge criteria are frequently met. Adsorbed metals are removed from the beads using dilute mineral acids. In many cases, the extracted metals are further concentrated to allow recycle of the metal values.

#### **Technology Performance**

Field testing of BIO-FIX bead technology to remove heavy metals from AMD waters has been conducted at four sites. These tests were conducted in cooperation with government agencies and private mining operations. Two of the field tests utilized a standard column system, while the other two tests employed a low-maintenance circuit developed to treat AMD problems in remote areas. The tests ranged in duration from two weeks to 11 months and more than 200,000 gallons of wastewater were processed. The results were encouraging and

indicated that drinking water standards and aquatic wildlife standards could be routinely achieved for copper, cadmium, lead, zinc, manganese, iron, cobalt, and nickel. BIO-FIX beads proved to be chemically and physically stable over repeated loading-elution cycles and were not affected by adverse climatic conditions such as cold temperature or heavy snows.

#### **Remediation Costs**

BIO-FIX technology has been licensed from the Bureau of Mines by three environmental remediation companies and is available for commercial application. Cost information will be supplied upon request.

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## **Biological Aqueous Treatment System**

### **PCP, Creosote Components, Gasoline and Fuel Oil Components, Chlorinated Hydrocarbons, Phenolics, and Solvents in Ground Water**

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#### **Technology Description**

The BioTrol aqueous treatment system (BATS) is a patented biological treatment system that is effective for treating contaminated ground water and process water. The system uses an amended microbial mixture, which is a microbial population indigenous to the wastewater to which a specific microorganism has been added. This system removes the target contaminants, as well as the naturally occurring background organics.

Contaminated water enters a mix tank, where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to an optimum temperature, using both a heater and a heat exchanger to minimize energy costs. The water then flows to the reactor, where the contaminants are biodegraded.

The microorganisms that perform the degradation are immobilized in a multiple-cell, submerged, fixed-film bioreactor. Each cell is filled with a highly porous packing material to which the microbes adhere. For aerobic conditions, air is supplied by fine bubble membrane diffusers mounted at the bottom of each cell. The system may also run under anaerobic conditions.

As the water flows through the bioreactor, the contaminants are degraded to biological end-products, predominantly carbon dioxide and water. The resulting effluent may be discharged to a publicly owned treatment works (POTW) or may be reused on site. In some cases, discharge with a National Pollutant Discharge Elimination System (NPDES) permit may be possible.

This technology may be applied to a wide variety of wastewaters, including ground water, lagoons, and process water. Contaminants amenable to treatment include pentachlorophenol, creosote components, gasoline and fuel oil components, chlorinated hydrocarbons, phenolics, and solvents. Other potential target waste streams include coal tar residues and organic pesticides. The technology may also be effective for treating certain inorganic compounds such as nitrates; however, this application has not yet been demonstrated. The system does not treat metals.

#### **Technology Performance**

During 1986 and 1987, BioTrol Inc., performed a successful 9-month pilot field test of BATS at a wood-preserving facility. Since that time, the firm has installed nine full-scale systems and has performed several pilot-scale demonstrations. These systems have successfully treated waters contaminated with gasoline, mineral spirit solvents, phenols, and creosote.

The SITE demonstration of the BATS technology took place from July 24 to September 1, 1989, at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. The system was operated continuously for 6 weeks at three different flow rates.

Results of the demonstration indicate that pentachlorophenol (PCP) was reduced to less than 1 part per million at all flow rates. Removal percentage was as high as 97 percent at the lowest flow rate. The Applications Analysis Report (AAR) (EPA/540/A5-91/001)

has been published. The Technology Evaluation Report (TER) will be available in 1992.

### Remediation Costs

No cost information is available.

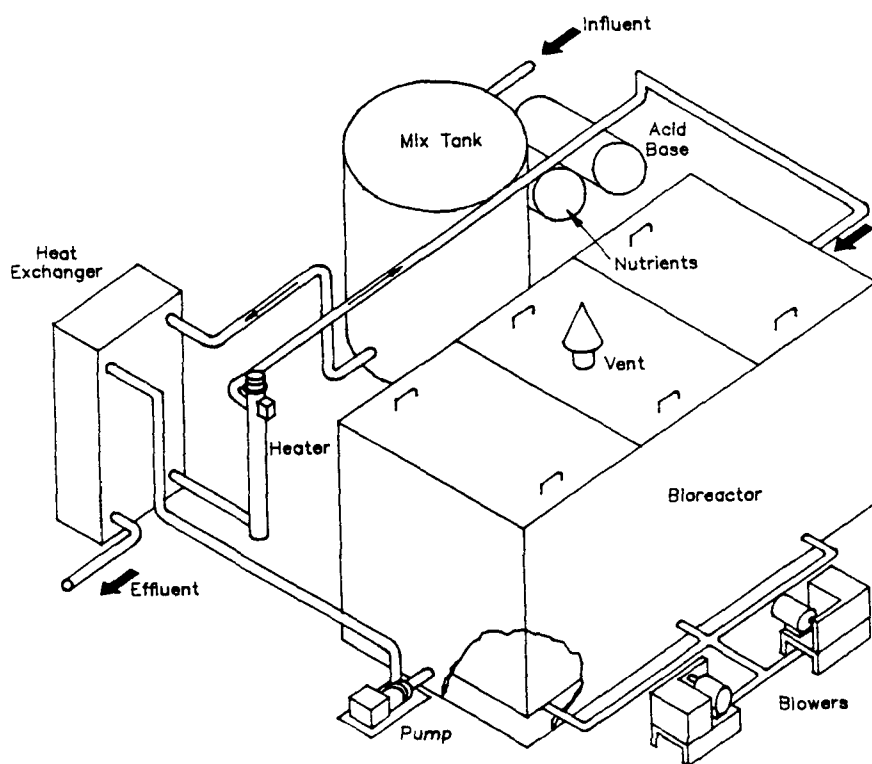
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Bioreactor processing system



## **Biological Degradation of Cyanide**

### **Decommissioning of Precious Metals Heap Leaching Facilities**

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#### **Technology Description**

This bacterial treatment system provides alternative rinsing technology for decommissioning precious metals heap leach facilities. This alternative increases the rate of cyanide degradation in heaps by activating natural populations of cyanide-oxidizing bacteria indigenous to the site and/or introducing additional populations of natural bacteria with known cyanide-degrading capabilities.

The bacteria-enhanced process increases the rate of cyanide rinsing from the heaps and enables complete water recycling. This has three major advantages: it eliminates the need for toxic or corrosive chemicals to destroy the cyanide in process solutions; it diminishes the amount of fresh water needed for cyanide rinsing; and it eliminates the water balance problem caused by the large volumes of contaminated wastewater generated during conventional rinsing that must be evaporated. Ideally, the bacteria-enhanced rinsing will completely and permanently destroy the cyanide in the process solutions as well as in the heaps.

To implement this technology, cyanide in the process water will be bacterially oxidized as it is pumped through the activated carbon columns in the gold recovery plant and the collection pond. Treated water, containing cyanide-degrading bacteria, is then used to rinse and degrade cyanide in the heaps. If the bacteria present in the rinse water are not sufficient, nutrients and/or known cyanide-oxidizing bacteria will be added to the heaps.

Incorporation of biological cyanide oxidation into precious metals heap decommissioning procedures will decrease the time required to meet final closure limits, decrease water requirements during the rinsing process, and

eliminate the need for toxic or corrosive chemicals for cyanide degradation.

#### **Technology Performance**

Commercial application of the process is designed to use the carbon adsorption columns in the gold recovery plant, the collection pond, or the heap as bioreactors. Laboratory tests were conducted to simulate these conditions. Bacteria effectively oxidized cyanide to varying degrees in each instance. For example, in tests designed to simulate the gold recovery plant, bacteria oxidized cyanide from between 50 and 170 ppm WAD CN in the feed solution to 0.1 ppm WAD CN in the treated water in <1 hour.

Field demonstration of the biological cyanide oxidation system is scheduled to occur during decommissioning of a Nevada heap leach operation in the Summer of 1992.

#### **Remediation Costs**

Cost information is not available.

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## Biological Treatment

### Nitrates, $\text{CCl}_4$ , and $\text{CHCl}_3$ in Ground Water (In Situ Treatment)

#### Treatment Description

This biological treatment system simultaneously removes nitrates and organics from contaminated ground water in situ. The technology relies on wells within the contaminated region to introduce and distribute nutrients to achieve favorable conditions for microbial metabolism of the contaminants. If indigenous bacteria do not possess the ability to destroy target compounds, other strains of aquifer microbes can also be introduced to the subsurface.

At DOE's Hanford Site, the technology will be demonstrated by remediating a portion of the aquifer which is contaminated with nitrates,  $\text{CCl}_4$ , and  $\text{CHCl}_3$ . The treatment process will use facultative anaerobic microorganisms isolated from the Hanford Site that have been shown to degrade both nitrates and  $\text{CCl}_4$ .

#### Technology Performance

Carbon tetrachloride and nitrate destruction by indigenous Hanford microorganisms has been demonstrated with simulated ground water in bench- and pilot-scale reactors. For example, a pilot-scale agitated slurry reactor processing a simulated ground-water feed containing 400-ppm and 200-ppb  $\text{CCl}_4$  and acetate as the primary carbon source, demonstrated greater than 99 percent and 93 percent destruction of nitrate and  $\text{CCl}_4$ , respectively. Work is proceeding to measure hydrodynamic and pertinent chemical properties of the proposed in situ bioremediation test site, and to rigorously study the kinetics of contaminant destruction and growth of the microorganisms. This information is being incorporated into 1- and 3-dimensional simulations of in situ

bioremediation to help design proper remediation conditions.

#### Remediation Costs

Cost information is not available at this time.

#### General Site Information

The Hanford Site, located in southeastern Washington State, is an area of approximately 600 square miles that was selected in 1943 for producing nuclear materials in support of the United States' effort in World War II. Hanford's operations over the last 40+ years have been dedicated to nuclear materials, electrical generation, diverse types of research, and waste management. Some of these operations have produced aqueous and organic wastes that were discharged to the soil column. In the 200 West area of the Hanford Site, plutonium recovery processes discharged  $\text{CCl}_4$ -bearing solutions to three liquid waste disposal facilities: a trench, tile field, and crib. A minimum of 637 tons of  $\text{CCl}_4$  was disposed to the subsurface, primarily between 1955 and 1973, along with co-contaminants such as tributyl phosphate, lard oil, cadmium, nitrates, hydroxides, fluorides, sulfates, chloroform, and various radionuclides, including plutonium. Near the disposal site,  $\text{CCl}_4$  vapors have been encountered in the vadose zone during well-drilling operations, and ground-water contamination from  $\text{CCl}_4$  covers 5  $\text{km}^2$ . Concentrations up to 1,000 times the EPA drinking water standard of 5 ppb have been measured in the ground water. In addition, nitrate concentrations up to 10 times the EPA drinking water standard of 44 ppm have been measured in the same area of the Site.

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## Bioremediation of Aromatic Hydrocarbons Unleaded Gasoline in Soil and Ground Water

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### Technology Description

Target contaminants for this treatment, are benzene, toluene, ethylbenzene, and xylenes (BTEX) in concentrations ranging from 1 ppb to 4 ppm. Site soil is placed in bioreactors and contaminated ground water is pumped through the bioreactors. Native microorganisms degrade the BTEX.

### Technology Performance

A pilot-scale demonstration was conducted at Naval Weapons Station Seal Beach in California. Three 80-litre-capacity bioreactors were used and operated at a capacity of 72 L per day or less. The treatment was evaluated using data from gas chromatography on the influent, effluent, and several sampling points during the process. The demonstration resulted in effluent water being cleaned to drinking water standards for BTEX.

### Remediation Costs

No cost information is available.

### General Site Information

The pilot-scale demonstration was conducted at an unleaded gasoline spill site at Naval Weapons Station Seal Beach in California between 1989 and 1991.

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## Bioremediation/Vacuum Extraction Petroleum Fuels in Soil

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### Technology Description

This process begins with removing soil contaminated with fuels and stockpiling it for treatment. This technology can be applied to soils contaminated with diesel, JP-5, or other fuels that have leaked from underground storage tanks.

In order to decontaminate the stockpiled soil, it is processed through a screen to eliminate rocks greater than four inches in diameter. The screened soil is transported to a site that is protected by a 40-milliliter liner with eight inches of sand base. A three-foot layer of contaminated soil is spread along the base of the prepared pile and then a series of vacuum extraction pipes are trenched in the soil and connected to a Vacuum Extraction System (VES) blower. The VES blower provides movement of oxygen through the pile. The remaining soil is piled into a trapezoid shape about 15 feet high, 200 feet long, and 60 feet wide. Fertilizer is added, and an irrigation system is installed. Computer-controlled sensors are placed within the pile to monitor temperature, pressure, and soil moisture.

### Technology Performance

The field pilot test conducted in Bridgeport, California, showed two results:

- After approximately two months of operation, the average concentration of total petroleum hydrocarbons (TPH) was 120 ppm; and
- The Navy declared the tested site was "clean" in a report prepared for the California Regional Water Quality Control Board.

### Remediation Costs

Remediation costs are estimated at approximately \$80 per ton of soil at the Bridgeport, California, pilot project.

### General Site Information

A field pilot test was conducted at Bridgeport, California in fiscal year 1989.

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## **Bioslurry Reactor**

### **PAH in Soils, Sediments, and Sludge**

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#### **Technology Description**

ECOVA Corporation's slurry-phase bioremediation (bioslurry) technology is designed to biodegrade creosote-contaminated materials by employing aerobic bacteria that use the contaminants as their carbon source. The technology uses batch and continuous flow bioreactors to process polycyclic aromatic hydrocarbon (PAH) contaminated soils, sediments, and sludges. Because site-specific environments influence biological treatment, all chemical, physical, and microbial factors are designed into the treatment process. The ultimate goal is to convert organic wastes into biomass, relatively harmless byproducts of microbial metabolism, such as carbon dioxide, methane, and inorganic salts. ECOVA Corporation conducted bench- and pilot-scale process development studies using a slurry phase biotreatment design to evaluate bioremediation of PAHs in creosote contaminated soil collected from the Burlington Northern Superfund site in Brainerd, Minnesota. Bench-scale studies are performed prior to pilot-scale evaluations in order to collect data to determine the optimal treatment protocols. Data obtained from the optimized pilot-scale program will be used to establish treatment standards for K001 wastes as part of the EPA's Best Demonstrated Available Technology (BDAT) program.

Slurry-phase biological treatment was shown to significantly improve biodegradation rates of 4- to 6-ring PAHs. The bioreactors are supplemented with oxygen, nutrients, and a specific inocula of microorganisms to enhance

the degradation process. Biological reaction rates are accelerated in a slurry system because of the increased contact efficiency between contaminants and microorganisms. Results from the pilot-scale bioreactor evaluation showed an initial reduction of 89.3 percent of the total soil-bound PAHs in the first two weeks. An overall reduction of 93.4 percent was seen over a 12-week treatment period.

Slurry-phase biological treatments can be applied in the treatment of highly contaminated creosote wastes. It can also be used to treat other concentrated contaminants that can be aerobically biodegraded, such as petroleum wastes. The bioslurry reactor system must be engineered to maintain parameters such as pH, temperature, and dissolved oxygen, with ranges conducive to the desired microbial activity.

#### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in spring 1991. From May through September 1991, EPA conducted a SITE demonstration using six bioslurry reactors at EPA's Test and Evaluation Facility in Cincinnati, Ohio. The reactors processed creosote-contaminated soil taken from the Burlington Northern Superfund site in Brainerd, Minnesota.

#### **Remediation Costs**

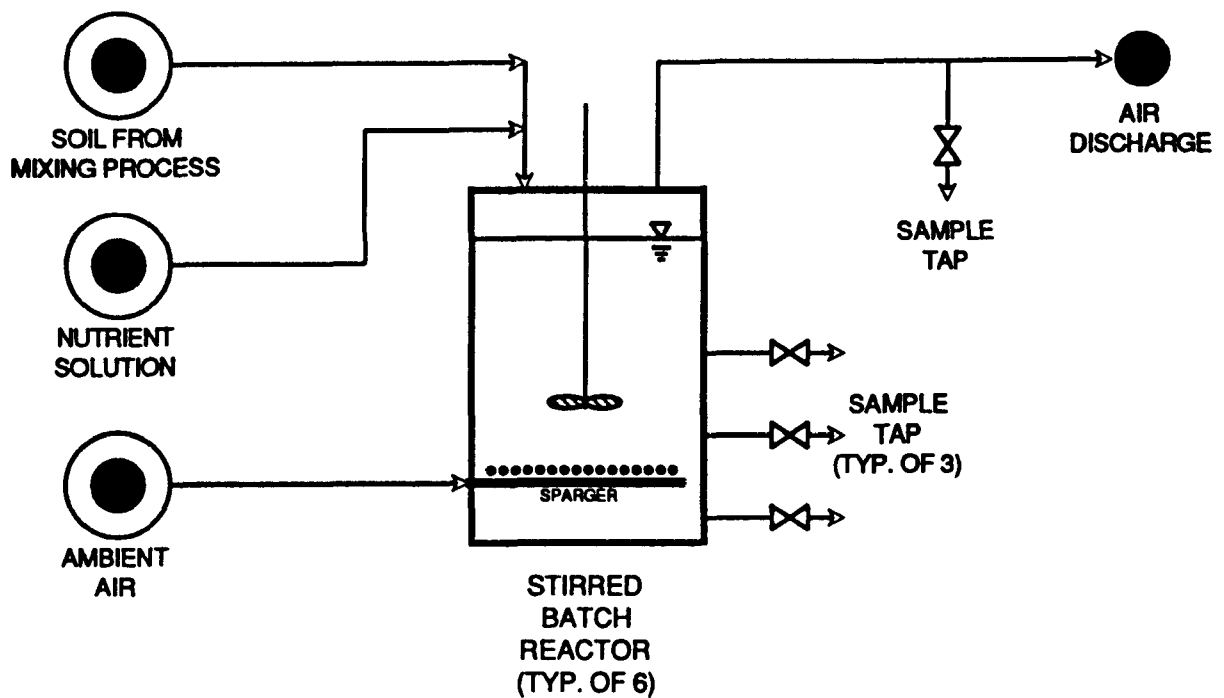
No cost information is available.



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Process flow diagram



## **Bioventing**

### **JP-5 Jet Fuel in Soil and Ground Water (In Situ Treatment)**

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#### **Technology Description**

This technology is used to treat soil and ground water contaminated with petroleum hydrocarbons. The treatment system consists of dewatering wells equipped with low vacuums to draw air through the contaminated zone and disperse the more volatile jet fuel components. Aeration of the vadose zone also promotes aerobic biodegradation of fuel hydrocarbons.

Water, soil vapor, and free fuel product are extracted from dewatering wells simultaneously. Any water/fuel mixture is separated in an oil/water separator, since the water requires treatment in a permitted plant. Vapor emissions should be low, below regulatory levels. Biodegradation occurs within the vadose zone.

Two limitations can affect use of this technology:

- Soil temperature should be kept above 10°C for optimal use of this technology;
- Heavy soils can impede, but do not inhibit, oxygen gas diffusion through subsoil.

#### **Technology Performance**

A pilot test of this technology is scheduled to be conducted in mid-1992 at Fallon Air Force Base in Nevada. In preparation for the test, in situ respirometry was performed at the site to test for potential effectiveness of the bioventing technology, and the respirometric data was compared to sites where bioventing has been successful.

Most of the contamination at the site is in an impure sand horizon at a 7-to-10-foot depth,

sandwiched between two clay lake bed strata. It is unknown how this scenario will affect achievement of cleanup goals.

Bioventing at the site is expected to continue for about 18 months. However, total time required for cleanup is unknown, since data on diesel and other low volatility fuels is lacking at this time.

#### **Remediation Costs**

Cost of this treatment, during the pilot test, is estimated at \$65/cubic yard of contaminated soil. This should be significantly higher than the cost for use of the technology in full-scale remedial operations.

#### **General Site Information**

The test is being conducted at a JP-5 leakage site at New Fuel Farm at Fallon AFB in Nevada. New Fuel Farm is being actively used by the Navy for aircraft refueling and will continue to be used throughout the test. In the treatment plot, which covers just over one acre, total TPH concentration is between 2,000 and 7,000 mg/kg (using California LUFT method). Benzene was detected in one soil sample at 0.1 mg/kg., and arsenic is naturally high in ground water.

The total contaminated plume at this site covers six acres.

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## Deep In Situ Bioremediation Process Organics in Soils

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### Technology Description

This process increases the efficiency and rate of biodegradation in deep contaminated soils. The specialized equipment system injects site-specific microorganism mixtures, along with the required nutrients, and homogeneously mixes them into the contaminated soils, without requiring any excavation. The injection and mixing process effectively breaks down fluid and soil strata barriers and eliminates pockets of contaminated soil that would otherwise remain untreated.

The process uses a twin, 5-foot-diameter dual auger system powered and moved by a standard backhoe. The hollow shaft auger drills into contaminated soil, allowing the microorganism and nutrient mixture(s) to be continually injected through a controlled nozzle system. If necessary, water, nutrients, and natural bacteria, are added to the contaminated area, as determined by a site-specific laboratory test program.

The distribution of the microorganisms and nutrients occurs during the initial auger action. The auger flights break the soil loose, allowing mixing blades to thoroughly blend the microorganism-and-nutrient mixture with the soil. The drilling occurs in an overlapping manner, to ensure complete treatment of all contaminated soil. The mixing action is continued as the augers are withdrawn. Treatment depth may exceed 100 feet.

The development of site-specific microorganisms is an integral part of the process. Laboratory bench-scale tests are performed on the contaminated soil to determine the water, nutrients, and, if necessary, bacteria required for successful biodegradation. Although some contaminants may volatilize

during remediation, volatilization has been minimized by adding a hood around the auger assembly and treating the captured vapors in a filter system.

The Dual Auger system was also developed for the treatment of inorganic contaminated soils, by injecting reagent slurry into the soil to solidify/stabilize contaminated waste.

Additionally, many sites require that an impermeable barrier/containment wall be constructed to prevent the continued migration of pollutants through the soil and water. This special feature allows for greater protection of the ground water and surrounding area.

The deep in situ bioremediation process may be applied to all organic-contaminated soils. Varying degrees of success may occur with different contaminants. High concentrations of heavy metals, non-biodegradable toxic organics, alkaline conditions, or acid conditions could interfere with the degradation process.

No residuals or wastes are generated in this process, as all of the treatment is performed beneath the ground surface. Upon completion of the remedial operations, the treated area can be returned to its original service.

### Technology Performance

This technology was accepted into the SITE Demonstration Program in June 1990. A demonstration project is tentatively planned for early fall 1992, in conjunction with the U.S. Air Force.

### Remediation Costs

No cost information is available.

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## Enhanced In Situ Biodegradation of Petroleum Hydrocarbons in the Vadose Zone

### Petroleum Hydrocarbons in Unsaturated Soil

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#### Technology Description

Bioventing is an in situ bioremediation technology that can be applied to the cleanup of unsaturated soils contaminated with petroleum hydrocarbons. The Air Force has identified more than 1,400 fuel contamination sites through the Installation Restoration Program and therefore feels that this technology will have very wide applicability.

Soil venting has been proven effective for the physical removal of volatile hydrocarbons from unsaturated soils. This technology can also provide oxygen for the biological degradation of the fuel contaminants. Common strains of soil bacteria have been proven capable of biodegrading fuel hydrocarbon components.

Through the optimization of the venting air flow rates and possible nutrient/moisture addition, the proportion of hydrocarbon removal by in situ biodegradation can be optimized. This approach may eliminate the need for off-gas treatment, thereby reducing overall site remediation costs.

This technology has a number of benefits:

- It does not require excavation of the contaminated material — this technology will treat soil in place;
- By optimizing the amount of hydrocarbon removal by in situ biodegradation and thereby minimizing the amount of hydrocarbons volatilized and removed in the off-gas, the requirement for off-gas treatment, such as catalytic incineration, may be eliminated. This can reduce the overall treatment cost by 50 percent;

- The less volatile residual fuel organics which may not be treated by soil venting alone can be treated with bioventing.

#### Technology Performance

The pilot-scale field test at Tyndall AFB in Florida was successful:

- Under optimum conditions, approximately 80 percent hydrocarbon removal could be attributed to the mechanism of in situ biodegradation;
- Biodegradation removal rates ranged from 2 to 20 mg/kg of soil per day; and
- Although additional nutrients and moisture did not affect biodegradation rates at this specific site, in situ soil temperatures did significantly affect these rates.

#### Remediation Costs

Remediation costs are estimated at approximately \$12 to \$15 per cubic yard of contaminated soil. This estimate assumes no off-gas treatment will be required.

#### General Site Information

A pilot-scale field test was conducted at POL Area B at Tyndall Air Force Base, Florida, between July 1989 and August 1990. This field study involved four small treatment plots, approximately twenty feet by six feet by five feet deep. The site was previously used as a JP-4 jet fuel storage area.

To determine the applicability of implementing bioventing technology in a sub-arctic environment, a pilot-scale feasibility study was started in July 1991 at a JP-4 jet fuel contamination site at Eielson AFB, Alaska. This effort is co-funded by the U.S. EPA to look at the effectiveness of soil warming techniques to enhance biodegradation rates and extend the season during which bioventing would be functional in a cold weather environment.

The Air Force Center for Environmental Excellence and the Air Force Civil Engineering Support Agency have developed a bioventing initiative plan to test bioventing at 40 Air Force sites contaminated with petroleum hydrocarbons. The purpose of this initiative is to gather sufficient scientifically valid operational data from bioventing systems to move this technology from being innovative to proven. Screening tests (air permeability and in situ respiration) will first be conducted at 50 potential sites. Based on the success of the screening tests, approximately 40 of the 50 sites will be chosen for long-term testing of bioventing.

To expand the range of site conditions for which bioventing is applicable and to further optimize the treatment process, a full-scale bioventing demonstration is scheduled to begin in Spring 1992. This field study will be conducted at an Air Force fuel contamination site in the northern United States. The effects of in situ soil temperature on biodegradation

rates will be explored in detail as well as the effectiveness of bioventing in a less permeable soil, bioventing optimization through well placement, and the use of in situ air sparging wells for bioventing air injections wells.

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## Enzyme Catalyzed, Accelerated Biodegradation Diesel Fuel, Heating Fuel Oil, Hydraulic Oils and Glycol in Soil

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### Technology Description

This treatment, called the Bio-Treat System®, involves ex situ bioremediation of contaminated soil in a biocell. The treatment site is located on a concrete pad with a surrounding drainage ditch allowing any runoff to flow into an oil/water separator. Using a 30-day treatment process, hydrocarbon degrading bacteria are applied twice, once on Day 1 and again on Day 8. Enzyme and nutrient are applied twice, once on Day 1 and again on Day 6. Polyphasic suspension agent (PSA) is applied five times on Days 1, 4, 8, 18, and 21. The products are applied with a garden hose, pump, and 300-gallon drum. The soil is tilled with a garden tractor after each product application and once each week.

Monitoring consists of initial waste screening using (EPA) tests 8015, 8020, 8240, and 8270. Post-treatment tests used depend on contaminants found in the waste during initial screening.

Rainfall can affect use of this process since it interferes with aerobic biodegradation, but covering the biocell can eliminate this limitation.

### Technology Performance

The U.S. Marine Corps Base at Camp Pendleton, California, conducted a pilot study of this technology in 1991 on contaminated soil from oil/water separator sumps at Camp Pendleton. Target contaminants were diesel, benzene, ethylbenzene, toluene, and xylenes, with an average TPH of 29,000 ppm. After 29 days of treatment, the process had reduced total petroleum hydrocarbons (TPH) to an average of

88 ppm, well below the 100 ppm goal of the study.

Capacity of the system used in the study was 50 cubic yards per month. (A larger system proposed could handle 10,000 cubic yards per month under an enclosed, storm-proof building.) Total time required for operation and maintenance was 40 days.

The process produced no residual waste. No future maintenance of the system was required. The remediated soils were hauled to a beneficial use area on base. No future monitoring was required by the local health department or water quality authority.

### Remediation Costs

Costs, including design, for the pilot study are estimated at \$351 per cubic yard of contaminated soil.

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## **Geolock and Bio-Drain Treatment Platform**

### **Biodegradable Contaminants in Soil**

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#### **Technology Description**

The Geolock and Bio-drain treatment platform is a bioremediation system that is installed in the soil or waste matrix. The technology can be adapted to soil characteristics, contaminant concentrations, and geologic formations in the area. The system is composed of an in situ tank, an application system, and a bottom water recovery system.

The Geolock tank, an in situ structure, is composed of high density polyethylene (HDPE), sometimes in conjunction with a slurry wall. An underlying permeable waterbearing zone facilitates the creation of ingradient water flow conditions. The tank defines the treatment area, minimizes intrusion of off-site clean water, minimizes the potential for release of bacterial cultures to the aquifer, and maintains contaminant concentration levels that facilitate treatment. The ingradient conditions also facilitate reverse leaching or soil washing. The application system, called Bio-drain, is installed within the treatment area. Bio-drain acts to aerate the soil column and any standing water. This creates an aerobic environment in the air pore spaces of the soil. Other gas mixtures can also be introduced to the soil column such as air/methane mixtures used in biodegradation of chlorinated organics. The cost of installation is low, and the treatment platforms can be placed in very dense configurations.

Existing wells or new wells are used to create the water recovery system for removal of water used to wash contaminated soil. By controlling the water levels within the tank, reverse leaching or soil washing can be conducted. The design of the in situ tank also controls and minimizes the volume of clean off-site water entering the system for treatment. In-gradient conditions minimize the potential for off-migration of contaminants. This also creates a condition such that the direction of migration of existing contaminants and bacterial degradation products is toward the surface.

Conventional biological treatment is limited by the depth of soil aeration, the need for physical stripping, or the need to relocate the contaminated media to an aboveground treatment system. The Geolock and Bio-drain treatment platform surpasses these limitations and reduces the health risks associated with excavation and air releases from other treatment technologies.

All types and concentrations of biodegradable contaminants can be treated by this system. Through direct degradation or co-metabolism, microorganisms can degrade most organic substances. Only a limited number of compounds, such as 1,4-dioxane, are resistant to biodegradation. In these cases, the material may be washed from the soil using surfactants. Arochlor 1254 and 1260, both polychlorinated

biphenyls (PCB), may now also be biodegradable in light of recent advancements by General Electric.

Extremely dense clays may be difficult to treat with this technology. Rock shelves or boulders may render installation impossible. Until equilibrium conditions are established, the only residuals for management would be the quantity of water withdrawn from the system to create in-gradient conditions. After equilibrium conditions are established the water would be treated in situ to meet National Pollutant Discharge Elimination System (NPDES) or pre-treatment limits.

### **Technology Performance**

The technology was accepted into the SITE Demonstration Program in August 1990. Two patents on the system were awarded in July and October of 1991. Site selection for the demonstration is currently underway.

### **Remediation Costs**

No cost information is available.

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## Immobilized Cell Bioreactor (ICB) Biotreatment System

Polycyclic Aromatic Hydrocarbons (PAH), Phenols, Gasoline,  
Chlorinated Solvents, Diesel Fuel, and Chlorobenzene in Ground Water

### Technology Description

The immobilized cell bioreactor (ICB) biotreatment system is an aerobic fixed-film bioreactor system designed to remove organic contaminants (including nitrogen-containing compounds and chlorinated solvents) from process wastewater, contaminated ground water, and other aqueous streams. The system offers improved treatment efficiency through the use of (1) a unique, proprietary reactor medium that maximizes the biological activity present in the reactor and (2) a proprietary reactor design that maximizes contact between the biofilm and the contaminants. These features result in quick, complete degradation of target contaminants to carbon dioxide, water, and biomass. Additional advantages include (1) high treatment capacity, (2) compact system design, and (3) reduced operations and maintenance costs resulting from simplified operation and slow sludge production. Basic system components include the bioreactor and medium, nutrient mix tank and feed pump, and a blower to provide air to the reactor.

Depending on the specifics of the influent streams, some standard pretreatments, such as pH adjustment or oil and water separation, may be required. Effluent clarification is not required for the system to operate, but may be required to meet the specific discharge requirements.

The ICB biotreatment system has been successfully applied to industrial wastewater and ground water containing a wide range of organic contaminants, including polycyclic aromatic hydrocarbons (PAH), phenols, gasoline, chlorinated solvents, diesel fuel, and chlorobenzene. Industrial streams amenable to treatment include wastewaters generated from chemical manufacturing, petroleum refining,

wood treating, tar and pitch manufacturing, food processing, and textile fabricating. Allied-Signal Corp. has obtained organic chemical removal efficiencies of greater than 99 percent. The ICB biotreatment system, because of its proprietary medium, is also very effective in remediating contaminated ground water streams containing trace organic contaminants. The ICB Biotreatment System can be provided as a complete customized facility for specialized treatment needs or as a packaged modular unit. The technology can also be used to retrofit existing bioreactors by adding the necessary internal equipment and proprietary media. The table below summarizes recent applications.

Table 1. Current Applications

<u>Applications</u>	<u>Contaminants</u>	<u>Scale</u>
Pipeline Terminal Wastewater	COD, Benzene, MTBE, Xylenes	Bench
Specialty Chemical Wastewater	Cresols, MTBE, PAH, Phenolics	Pilot
Groundwater	Chlorobenzene, TCE	Pilot
Tar Plant Wastewater	Phenol, Cyanide, Ammonia	Pilot
Wood Treating Wastewater	Phenolics, Creosote	Commercial

## Technology Performance

The G&H Landfill in Utica, Michigan, was selected for the demonstration of the ICB system. Treatability studies have shown the system's ability to biodegrade all the priority pollutants present to low part per billion levels. Currently, the demonstration plan is being finalized. The actual SITE Demonstration is tentatively planned for summer 1992. Allied-Signal, Inc., is currently operating an anaerobic system to reduce the concentrations of trichloroethylene and other chlorinated compounds in contaminated ground water.

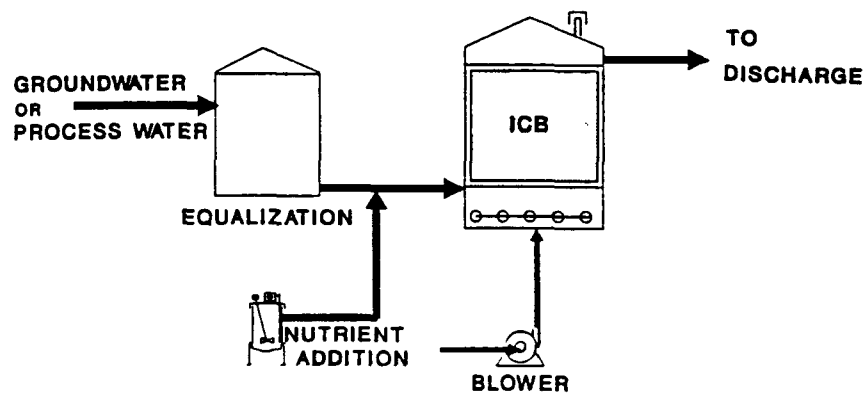
## Remediation Costs

No cost information is available.

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Allied-Signal immobilized cell bioreactor



## In Situ Biodegradation

### Fuels, Fuel Oils and Non-halogenated Solvents in Soil and Ground Water

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#### Technology Description

This in situ biodegradation process treats soil or ground water contaminated with hydrocarbons such as fuels, fuel oils, and non-halogenated solvents. This technology can be applied to fuel spills, leaky storage tanks, and fire training pits.

Nutrients (especially nitrogen and phosphorus), soil-conditioning chemicals, and an electron acceptor (oxygen source or nitrate) are introduced to the aquifer through irrigation wells, ditches, or soil surface irrigation. Pumping wells remove excess fluids or contaminated ground water. Contaminated water can be treated on the surface or reinjected for treatment in the soil. Monitoring wells must be placed within and surrounding the site.

#### Technology Performance

Two field tests of this process have been completed using hydrogen peroxide as the electron acceptor. The first test was conducted at Kelly Air Force Base in Texas, the second at Eglin AFB in Florida. Neither site was ideal for this method. At Kelly AFB, the injection wells became clogged from precipitation of calcium phosphate, which reduced their injection capacity by 90 percent. At Eglin AFB, problems with the aquifer plugging due to iron precipitation were encountered in addition to the rapid decomposition of hydrogen peroxide. These field tests showed that the design of hydraulic delivery systems and the compatibility of injection chemicals with soil minerals is as important to successful treatment as the enhancement of bacteria.

#### Remediation Costs

Exclusive of site characterization, one estimate of the cost range of this method is from \$160 to \$230 per gallon of residual fuel removed from the aquifer. Monitoring would be expensive, depending upon the type of contaminant. Site characterization must be done to determine soil/chemical compatibility.

#### General Site Information

Field tests conducted at Kelly AFB, Texas, and Eglin AFB, Florida, were completed at JP-4 jet fuel contamination sites. A third field demonstration is planned to start in Summer 1992 in which nitrate would be added to the aquifer to enhance the anoxic degradation of the benzene, toluene, xylene, and ethylbenzene (BTEX) fraction of jet fuel. A Fuel contamination site at Eglin AFB is currently being investigated for this demonstration.

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## **In Situ Biodegradation TCE in Ground Water**

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### **Technology Description**

Picatinny Arsenal is the USGS Toxic Waste Hydrology Program's national demonstration site for chlorinated solvents in ground water. Earlier work has looked at many of the processes which can affect the fate and transport of TCE in the system, including volatilization to the unsaturated zone, aerobic biodegradation, anaerobic biodegradation, and sorption/desorption to/from aquifer sediments. Solute transport modeling has also been done to integrate these studies.

The distribution of TCE in the soil gas has been determined by the installation and sampling of 50 vapor probes at the site. A strong disequilibrium has been found to exist between the soil and vapor TCE concentrations. That is, there is much more TCE on the soil than predicted based on the soil gas TCE concentrations. Similarly, more TCE has been found in soil water than predicted based on the soil gas TCE concentrations.

Work on determining the feasibility of using aerobic in situ biodegradation of TCE vapors as a remediation strategy at Picatinny Arsenal has begun. This work has been funded by the U.S. Environmental Protection Agency. Laboratory microcosm studies using soil from near the source of the TCE contamination have been conducted and results show that the indigenous methanotrophic bacteria from this site can cometabolically degrade vapor-phase TCE when appropriate amounts of methane, oxygen, and nutrients are amended to soil microcosms.

### **Technology Performance**

Up to 82 percent removal of vapor-phase TCE concentration has been observed after only eight days in these laboratory tests. A pilot-scale facility utilizing this technology is proposed for the field site. It will include either venting the soil in the unsaturated zone or sparging a contaminated well near the source to produce a vapor stream containing TCE. The vapor stream will be amended with appropriate amounts of a degradable hydrocarbon (methane, propane, or natural gas) and oxygen, and then either (1) reinjected into the unsaturated zone to allow in situ remediation to take place, or (2) channeled into an above-ground soil bioreactor to allow remediation to take place.

Anaerobic TCE degradation has been documented to occur in the saturated zone at Picatinny Arsenal. The rates of reductive dehalogenation of TCE to cis-1,2-dichloroethylene to vinyl chloride were measured in soil microcosm studies using aquifer sediments from the plume. Anaerobic TCE degradation is an active and viable in situ remediation process at the site. Enhancement or stimulation of this process is the subject of proposed study.

Experiments looking at the sorption/desorption of TCE from saturated zone sediments have shown that desorption of TCE from long-term contaminated sediments is kinetically slow. A disequilibrium has been found to exist between the soil and water TCE concentrations in the aquifer. That is, there is much more TCE on

the sediments than would be predicted based on the measured TCE concentrations in ground water. These findings infer that pump-and-treat remediation will not remove the major pool of TCE in the system which is TCE on the sediments.

The use of surfactants to increase removal of TCE from an aquifer also is the subject of proposed study. Laboratory tests will be conducted to determine the effect of introducing a surfactant on the hydraulic properties of the aquifer and the apparent solubility of TCE in the aquifer. A field-scale experiment is proposed to determine the effectiveness of the chosen surfactant on the contaminated aquifer system at Picatinny Arsenal. If successful, this approach will address the need to get the TCE off of the sediment and into the aqueous phase for remediation.

A solute-transport model has been modified to facilitate transport of more than one solute at a time and also include reactions between these difference solutes. This state-of-the-art modeling effort will be used to include the appearance and disappearance of breakdown products and to incorporate the determined reaction rates between these products. Also, the measured rates of desorption and volatilization will be input so the model will be able to integrate the effects of all the different processes investigated to come up with a more accurate simulation of the distribution and transport of TCE at the site.

## **Remediation Costs**

No cost information is available at this time.

## **General Site Information**

Contamination of ground water, primarily with TCE, at Picatinny Arsenal, New Jersey, has been caused by improper disposal of wastewater from a metal plating/degreasing operation. Picatinny Arsenal is a federally owned property operated by the U.S. Army. The New Jersey District of the USGS has had a long history of favorable cooperation with the Army at this site.

The TCE ground-water plume (1,000 feet wide by 2,000 feet long by 60 feet thick) at Picatinny Arsenal has been well characterized over the past 10 years by the USGS. The plume is one of the world's best instrumented with TCE distribution being defined both areally and vertically by the installation and sampling of 15 drive-point sites and 75 observation wells. Samples have been analyzed for volatile organic chemicals (VOCs), major cations and anions, trace elements, nutrients, and dissolved organic carbon. The hydrology of the plume area is well known and is included in the area of an existing three-dimensional ground-water flow model. The geology of the plume area has been defined by lithologic logs, geophysical logs, and particle size analysis.

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## **In Situ Enhanced Bioremediation Jet Fuel in Ground Water**

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### **Technology Description**

The approach used in this process involves enhanced bioremediation. Once initial tests have been done to determine that naturally occurring microbes, present in the aquifer, are capable of degrading the contamination, the rate-limiting nutrients are determined. Ground Water is pumped from an uncontaminated source with low concentrations of dissolved iron and amended by adding the necessary nutrient(s). The amended water is pumped into a series of infiltration galleries (french drains) laterally transecting the contamination plume. Approximately 20 feet downgradient from the infiltration galleries, a line of extraction wells pumps contaminated ground water out of the ground and discharges it to a permitted treatment facility. Several observation wells in the area are monitored to evaluate the effectiveness of the system.

### **Technology Performance**

Testing of this process of being done at the Defense Fuel Supply Point, Hanahan, South Carolina. Laboratory experiments have shown that microbes capable of degrading the contamination occur naturally in contaminated ground water at the site. Examination of field data showed that microbial degradation of organic contaminants was occurring at the site. The terminal electron accepting processes occurring in most areas of the site were sulfate reduction and methanogenesis. In part of the contaminated ground water, respirative activity was significantly reduced relative to fermentative activity. Laboratory tests demonstrated that replacement of the pore water with sterile, uncontaminated water amended with nitrate was sufficient to stimulate respirative activity in the aquifer sediment.

Field testing of the bioremediation system was scheduled to begin in late summer 1992.

### **Remediation Costs**

No cost information is available at this time.

### **General Site Information**

The test site is a fuel tank farm at Defense Fuel Supply Point, Hanahan, South Carolina. The contamination is dominantly JP-4 jet fuel, and the target compounds are benzene, toluene, ethylbenzene, and xylene (BTEX). The ground-water contamination extends off the facility property and into a nearby neighborhood. The bioremediation system is divided into three major sections. The bioremediation approach at each of the three sections will differ to allow conclusions to be drawn regarding the reactive effectiveness of the approaches.

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## **Liquids and Solids Biological Treatment (LST)**

### **Biodegradable Organics in Soils, Sediments, and Sludge**

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#### **Technology Description**

Liquid and solids biological treatment (LST) is a process that can be used to remediate soils and sludges contaminated with biodegradable organics. The process is similar to activated sludge treatment of municipal and industrial wastewaters, but it occurs at substantially higher suspended solids concentrations (such as greater than 20 percent) than are encountered in activated sludge applications. An aqueous slurry of the waste material is prepared and environmental conditions (for example, nutrient concentrations, temperature, and pH) are optimized for biodegradation. The slurry is then mixed and aerated for a sufficient time to degrade the target waste constituents. LST systems can be designed for either batch or continuous operations.

Several physical process configurations are possible for LST of contaminated soil and sludges, depending on site- and waste-specific conditions. Batch or continuous treatment can be conducted in impoundment-based reactors. This is sometimes the only practical and economically viable option for very large (greater than 10,000 cubic yards) projects. Alternatively, tank-based systems may be constructed. Considerable differences can exist between applications in which LST is a viable remedial option. Consequently, selection of the most appropriate operational sequence must be determined on a case-specific basis.

Constituent losses due to volatilization are often a concern during LST operations. The potential for emissions is greatest in batch treatment systems and lowest in continuously stirred tank reactor (CSTR) systems, particularly those with

long residence times. Various technologies (such as carbon adsorption and biofiltration) can be used to manage emissions.

Bioremediation by LST may require a sequence of steps involving pre- and post-treatment operations. The only instance in which multiple unit operations are not required is strictly in situ applications where treated sludge residues are destined to remain in place.

An alternative to landfilling of treated solids from an LST process is to conduct overall bioremediation in a hybrid system consisting of both an LST and land treatment system. Combining these two approaches may, for example, be desired to rapidly degrade volatile constituents in a contained system thereby rendering the material suitable to soils in a land-based system for long-term biostabilization.

Remediation Technologies, Inc., (ReTeC) has constructed a mobile LST pilot system that is available for field demonstrations. The system consists of two reaction vessels, two holding tanks, and associated process equipment. Tank operating volumes are 2,000 gallons. The reactors are aerated using coarse bubble diffusers and mixed using axial flow turbine mixers. The reactors can be operated separately or in combination as batch or continuous systems to allow a range of treatment conditions oxygen, and pH are continuously monitored and recorded. Additional features include antifoaming and temperature control systems. Pre- and post-treatment equipment is provided separately depending on site-specific circumstances and project requirements.

The technology is suitable for treating sludges, sediments, and soils containing any biodegradable organic materials. To date, the process has been used mainly for treating

sludges containing petroleum and wood preservative organics such as creosote and pentachlorophenol. Polycyclic aromatic hydrocarbons, pentachlorophenol, and a broad range of petroleum hydrocarbons (such as fuels and oils) have been successfully treated with LST in the laboratory and the field.

### **Technology Performance**

ReTeC is currently seeking a private party to co-fund a 3-to-4-month demonstration of LST technology on an organic waste.

ReTeC has applied the technology in the field over a dozen times to treat wood preservative sludges in impoundment-type LST systems. In addition, two field-based pilot demonstrations and several laboratory treatability studies have been conducted for the treatment of petroleum refinery impoundment sludges.

### **Remediation Costs**

No cost information is available.

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## **PACT® Treatment System**

### **Hazardous Organics in Ground Water**

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#### **Technology Description**

Zimpro/Passavant Environmental Systems, Inc., has adapted the PACT® wastewater treatment system to the treatment of contaminated ground waters that are encountered at many Superfund sites. The system combines biological treatment and powdered activated carbon (PAC) adsorption to achieve treatment standards that are not readily attainable with conventional technologies. A system can be mounted on a trailer and function as a mobile unit, having a treatment capacity range of 2,500 to 10,000 gallons of wastewater per day. Larger stationary systems, treating up to 53 million gallons per day, are already in operation. With this technology, organic contaminants are removed from the wastewater through biodegradation and adsorption on the PAC. Living microorganisms (biomass) and PAC contact the wastewater in the aeration basin. The biomass removes biodegradable organic contaminants. PAC enhances the biological treatment by the adsorption of toxic organic compounds.

The degree of treatment achieved by the system depends on the influent waste characteristics and the system's operating parameters. Important characteristics include biodegradability, absorbability, and concentrations of toxic inorganic compounds, such as heavy metals.

The technology is adjusted to the specific waste stream by controlling the flow rate of the influent waste, recycle streams, and air, by varying the concentration of PAC in the system, and by adjusting the retention time of the mixed liquid, and volume ratio of the waste to biomass. If necessary, the temperature and Ph of incoming waste can be adjusted and nutrients can be added.

After completion of the aeration cycle, solids (PAC with adsorbed organics, biomass, and inert solids) are removed in the settling tank. The removed solids are partially returned to the aeration tank with the excess quantity diverted to the thickener where the solids are concentrated. The overflow from the thickener is returned to the aeration tank and the concentrated solids are removed. Dewatered solids may be regenerated to recover PAC.

A two-stage system can be applied where environmental regulations require the virtual elimination of organic priority pollutants or toxicity in the treated effluent. In the first stage aeration basin, a high concentration of biomass and PAC is used to achieve the removal of most of the contaminants. The second-stage aeration basin is used to polish the first-stage effluent. The virgin PAC added just ahead of the second-stage and the counter-flow of solids to the first-stage increases process efficiency. The excess solids from the first-stage are removed and treated as described in the single-stage PACT® system.

This technology can be applied to municipal and industrial wastewaters, as well as ground water and leachates containing hazardous organic pollutants. It has successfully treated various industrial wastewaters, including chemical plant wastewaters, dye production wastewaters, pharmaceutical wastewaters, refinery wastewaters, and synthetic fuel wastewaters, in addition to contaminated ground water and mixed industrial and municipal wastewater. In general, the system can treat liquid wastes with a chemical oxygen demand (COD) of up to 60,000 parts per million (ppm) including toxic volatile organic compounds up to 1,000 ppm. The developer's treatability studies have shown that the system can reduce the organics in contaminated ground water from several

hundred ppm to below detection limits (parts per billion range).

### Technology Performance

Contaminated ground water from several sites has been tested and found suitable for treatment. Site-specific conditions have prevented demonstration testing. Additional sites are now being evaluated for full demonstration of the PACT® system.

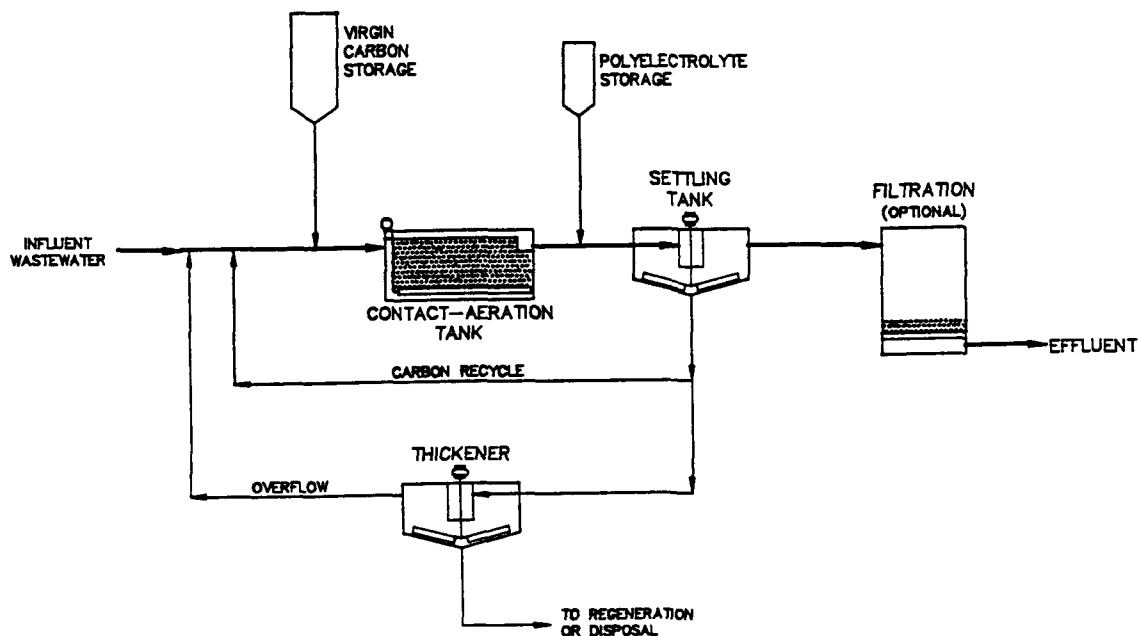
### Remediation Costs

No cost information is available.

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PACT® Wastewater Treatment System General Process Diagram



## Soil Slurry-Sequencing Batch Bioreactor Explosives (TNT, RDX, HMX) in Soil

### Technology Description

In this treatment process, explosives-contaminated soils and water are biologically treated in a tank or reactor. This treatment may be applied to soils contaminated with TNT, RDX, HMX, and other potential wastes associated with explosives. Contaminated soils are excavated and pre-screened to remove large rocks and debris. During the *Fill* period, the soils are mixed with water to produce a water-based slurry (typically 10-40 percent solids by weight) and pumped into the reactors. The reactors are designed and instrumented with various process controls. After the *Fill*, a chemical feed system will deliver required amounts of co-substrate, nutrients, nitrate, and Ph adjusting chemicals.

During the *React* period which follows, the mixers remain on and the microbial consortium degrades contaminants. When oxygen is serving as the exogenous electron acceptor, the aeration and mixing system is used to suspend the slurry. When nitrate is the electron acceptor, only the mixing system is used. In either case, the co-substrate serves as the primary carbon source. The time provided for the *React* cycle is dictated by the rate at which the explosive are degraded.

The mixed, treated slurry is then removed from the reactor in the *Draw* cycle and dewatered. Process water is recycled to the extent possible.

Operation of the Soil Slurry-Sequencing Batch Bioreactor depends on three factors:

- Enhancement of appropriate microbial consortia;

- Operations under appropriate conditions with a suitable electron acceptor; and
- Daily replacement of a volume of soil to provide new soil for microbial processing.

This treatment technology is best suited for sites contaminated with small volumes of contaminated soil where incineration would be cost prohibitive.

### Technology Performance

Previous bench-scale studies using soils contaminated with explosives from Joliet Army Ammunition Plant (JAAP) demonstrated the feasibility of this technology. Using microbial consortia isolated from JAAP, bench-scale studies showed that microbial degradation of contaminated soils could be accomplished with electron acceptors under aerobic and anoxic conditions with malate as a co-substrate. Aerobic reactors reduced TNT concentrations from about 1,300 mg/kg to less than 10 mg/kg in 15 days. Anoxic reactors achieved the same kind of reduction but at a slower rate. The same study indicated that this technology was the most suitable reactor system for full-scale implementation. A pilot-scale field demonstration using the technology is scheduled to begin during FY 1992.

### Remediation Costs

No cost information is available.

### General Site Information

Joliet Army Ammunition Plant is located in Joliet, Illinois. JAAP is a government-owned,

contractor-operated installation currently maintained in a non-producing, standby condition. JAAP is divided into two major functional areas: a load-assemble-pack (LAP) area and a manufacturing area. The LAP area contains munitions filling and assembly lines, storage magazines, and a demilitarization area. The LAP was placed on the National Priorities List in 1989. Soils from Group 61 in the LAP area will be used in the demonstration project.

Group 61 was constructed in 1941 to support World War II efforts and has been the site of demilitarization operations for various munitions. During these operations, steam was used to remove the explosives from munitions. The solids in the contaminated process water were settled out in a sump and the overflow water was discharged into a 10-acre ridge and furrow system (evaporating pond). The primary explosive contaminant is 2,4,6-TNT with concentrations ranging from 20-14,400 mg/kg.

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## **Chemical Treatment**



## Base-Catalyzed Decomposition Process PCBs and PCPs in Soils and Sediments

### Technology Description

The Base-Catalyzed Decomposition Process (BCDP) is a dehalogenation/dechlorination process that strips off chlorine in the PCB molecule and forms sodium chloride and biphenyls. The BCDP uses a rotary reactor in which most of the decomposition takes place. The contaminated soil is screened, processed with a crusher and pug mill, and stockpiled.

Next, in the main treatment step, this stockpile is mixed with sodium bicarbonate ( $\text{NaHCO}_3$ ). The sodium bicarbonate is used in an amount equal to about 10 percent of the weight of the stockpile. The mixture is then heated for about one hour at 630°F in the rotary reactor. PCBs are decomposed and partially volatilized in this step.

The clean soil removed from the reactor can be returned to the site. Off-gases from this reactor, which contain dust and trace amounts of PCBs, are filtered, scrubbed, and vented to the atmosphere. PCBs in the vapor condensate, residual dust, spent carbon, and filter cake are decomposed in a stirred-tank slurry reactor. The resulting sludge can be disposed of in the same manner as municipal sewage sludge.

### Technology Performance

Under the EPA SITE Demonstration Program, this process is scheduled to be used to treat PCB-contaminated soil at a U.S. Navy site in Stockton, California, in June 1992. Another field demonstration using this technology began in September 1991 at the U.S. Public Works

Center, Guam, and will be followed by full-scale remediation at that site. The goal of the Guam project is to produce treated soil containing 2 ppm or less for each congener and that will meet TSCA requirements for return to its original site or disposal in an unrestricted landfill.

### Remediation Costs

Cost of this process is estimated at \$245 per ton. Total cost of the Guam project, exclusive of site investigation, will be \$7 million. The system requires approximately two hours of maintenance for every 20 hours of operation.

### General Site Information

The field demonstration and full-scale remediation are underway at the U.S. Public Works Center, Guam. An estimated 5,500 tons of soil, containing 25 ppm or more PCBs, is scheduled for treatment.

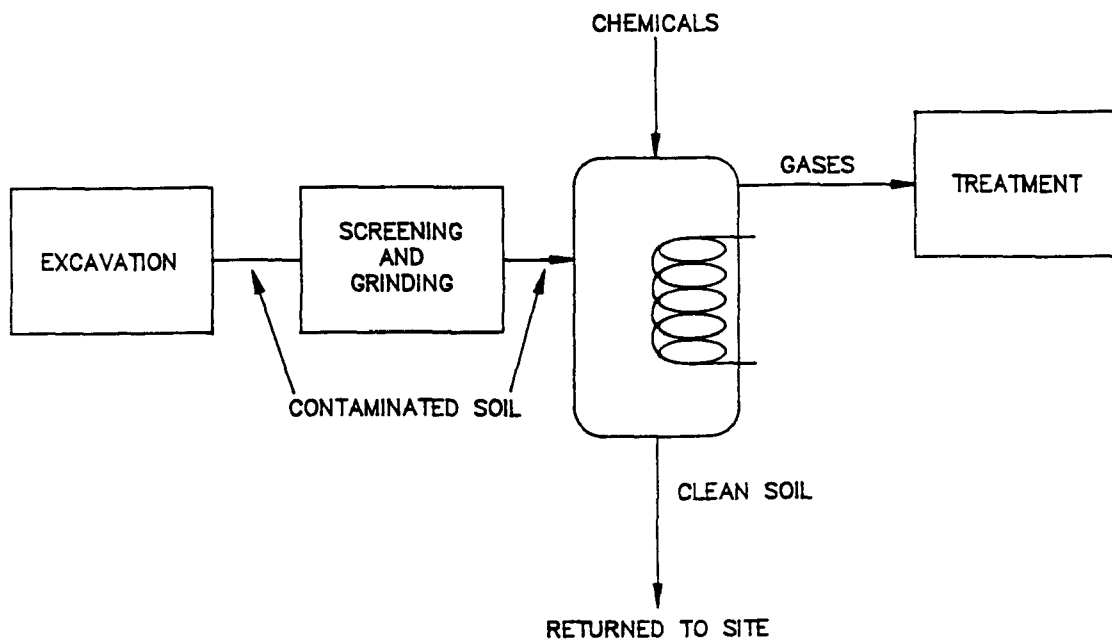
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Process Flow Chart



## Chemical Detoxification of Chlorinated Aromatic Compounds Dioxin and Herbicides in Soil

### Technology Description

This chemical detoxification of chlorinated aromatic compounds treats soils that have been contaminated with dioxin, herbicides, or other chlorinated aromatic contaminants.

The contaminated soil is excavated and a determination of the water content is made. If the water content is too high, the soil is dehydrated. Soil is placed in the reactor with the reagent and heated to 100°C to 150°C. The reagent is a 1:1:1 mixture of potassium hydroxide, polyethylene glycol, and dimethyl sulfoxide. After reaction, the reactor is drained and the soil is rinsed with clean water to remove excess reagents. Treated soil might be replaced in its original location depending upon the effectiveness of the decontamination and local environmental regulations.

### Technology Performance

Demonstrations of this method achieved greater than 99.9 percent decontamination. Several advantages of this method were indicated:

- It is relatively inexpensive for contaminants at low concentrations (in the ppm range);
- The reagents can be recycled;
- The products of the decontamination are not toxic and are not biodegradable;
- Bioassay studies show that the reaction products do not bioaccumulate or bioconcentrate; they do not cause mutagenicity, nor are they toxic to aquatic organisms or mammals;

- The chlorine atoms are replaced by glycol chains producing non-toxic aromatic compounds and inorganic chloride compounds; and
- The equipment components are commercially available.

Despite the numerous advantages of this technology, it also has limitations:

- For high contaminant concentrations, in the percent range, incineration could be less expensive to use;
- Water might interfere with the reactions between the reagents and the chlorinated aromatic compounds; and
- Some chlorinated compounds, such as hexachlorophene-24, are not degraded as effectively as others.

### Remediation Costs

The costs are in the range of \$100 to \$200 per ton. The Naval Civil Engineering Laboratory (NCEL) reports that the costs might be on the order of \$300 per cubic yard. The most expensive item is the reagent.

## **General Site Information**

Small-scale pilot testing was conducted on dioxin-contaminated soil in the laboratory. Larger-scale pilots are planned for the near future by the EPA laboratory at Edison, New Jersey.

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## **Chemical Oxidation and Cyanide Destruction**

### **Organics and Cyanide in Ground Water and Soil (In Situ Treatment)**

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#### **Technology Description**

This technology uses chlorine dioxide, generated on site by a patented process, to oxidize organically contaminated aqueous waste streams and simple and complex cyanide in water or solid media. Chlorine dioxide is an ideal oxidizing agent, because it chemically alters contaminants to salts and non-toxic organic acids.

Chlorine dioxide gas is generated by reacting sodium chlorite solution with chlorine gas, or by reacting sodium chlorite solution with sodium hypochlorite and hydrochloric acid. Both processes produce at least 95 percent pure chlorine dioxide. In aqueous treatment systems, the chlorine dioxide gas is fed into the waste stream through a venturi, which is the driving force for the generation system. The amount of chlorine dioxide required depends on the contaminant concentrations in the waste stream and the concentration of oxidizable compounds, such as sulfides.

In soil treatment applications, the chlorine dioxide may be applied in situ through conventional injection wells or surface flushing. The concentration of chlorine dioxide would depend on the level of contaminants in the soil.

Chlorine dioxide treatment systems have been applied to (1) drinking water disinfection, (2) food processing sanitation, and (3) waste remediation. Chlorine dioxide has also been

used as a biocide in industrial process water. Since chlorine dioxide reacts by direct oxidation rather than substitution (as does chlorine), the process does not form undesirable trihalomethanes.

This technology may be applied to aqueous waste streams, liquid storage vessels, soils, contaminated ground water, or any leachable solid media contaminated by a wide range of waste materials. Cyanides, sulfides, organo-sulfur compounds, phenols, aniline, and secondary and tertiary amines are examples of contaminants that can be remediated with this process.

#### **Technology Performance**

The SITE Demonstration Program has accepted two proposals from Exxon Chemical Company and Rio Linda Chemical Company to perform two separate demonstrations: one of cyanide destruction and the other of organics treatment. The cyanide destruction technology is scheduled to be demonstrated at EPA's Test and Evaluation facility in Cincinnati, Ohio. Site selection for the organics treatment technology is underway.

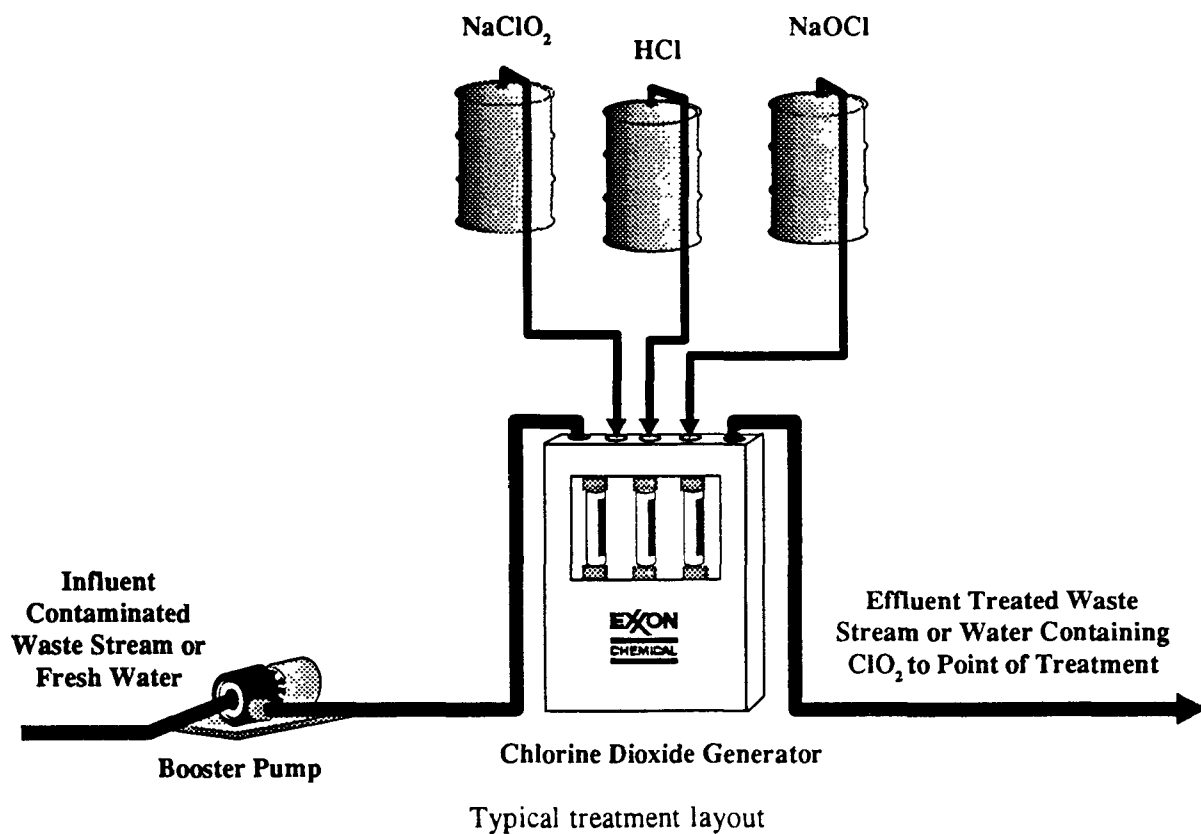
#### **Remediation Costs**

No cost information is available.

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## **Combined Chemical Binding, Precipitation, and Physical Separation Heavy Metals and Radionuclides in Water, Sludges, and Soils**

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### **Technology Description**

This chemical binding and physical separation method involves rapid, turbulent mixing of the proprietary material which consists of a fine powder (RHM 1000) containing complex oxides and other reactive binding agents. RHM 1000 absorbs, adsorbs, and chemisorbs most radionuclides and heavy metals in water, sludges, or soils (preprocessed into slurry), yielding coagulating, flocculating, and precipitating reactions. The pH, mixing dynamics, and processing rates are carefully chosen to optimize the binding of contaminants. Tests have shown that as little as 0.05% RHM 1000 per test run is needed for maximum binding. Water is separated from the solids by using a reliable, economical, two-stage process based on (1) particle size and density separation, using clarifier technology and micro-filtration of all particles and aggregates, and (2) dewatering, using a sand filter to produce a concentrate of radionuclides, heavy metals, and other solids. The material that is collected is stabilized and ready for disposal.

The process is designed for continuous throughput for water (50 to 1500 gpm). This technology can accommodate trace levels of naturally-occurring radioactive materials (NORM), and low-level radioactive wastes. The equipment is trailer-mounted for use as a mobile field system.

Larger capacity systems could be skid-mounted. The technology can be used for (1) cleanup and remediation of water, sludges, and soils contaminated with radium, thorium, uranium and heavy metals from uranium mining and milling operations, (2) cleanup of water containing NORM and heavy metals from oil and gas drilling, and (3) cleanup and remediation of man-made radionuclides stored in underground tanks, pits, ponds, or barrels. This technology has not yet been tested for water containing tritium.

### **Technology Performance**

This technology was accepted into the EPA SITE Demonstration Program in July 1990. EPA is seeking a suitable site to demonstrate this technology.

Possible disposal methods of the stabilized end product would be those required for low-level radioactive contamination.

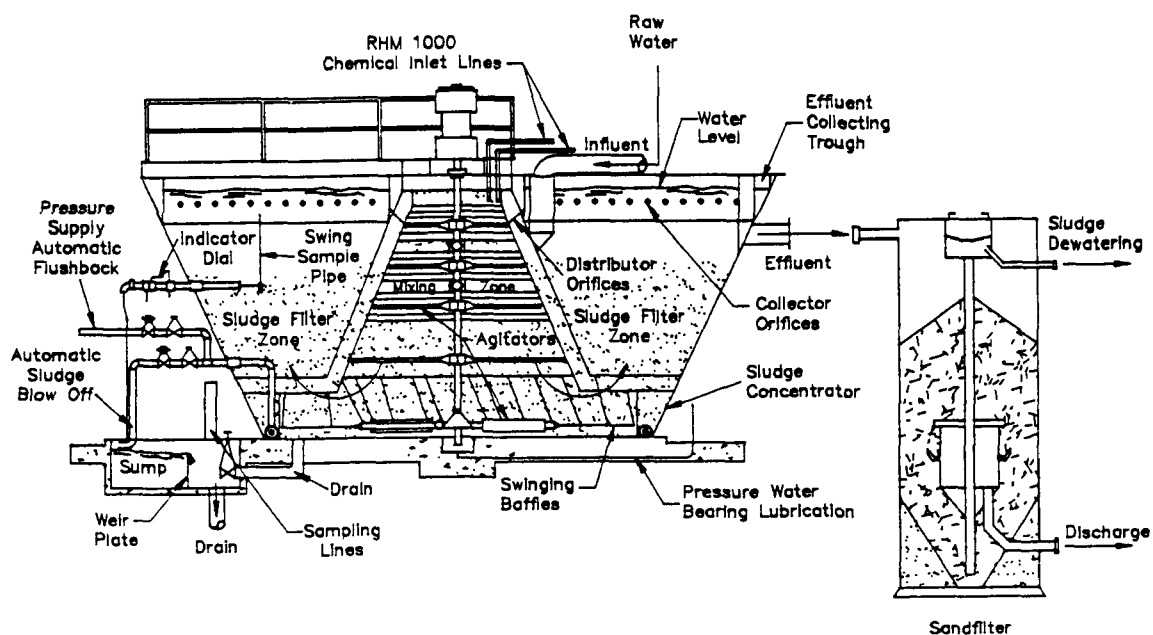
### **Remediation Costs**

No cost information is available.

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Schematic diagram of continuous operation for removing radionuclides and heavy metals from contaminated wastewater.



## DeChlor/KGME Process

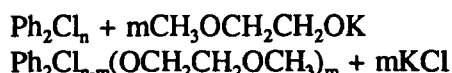
### Halogenated Aromatic Compounds and PCBs in Soils and Waste Streams (In Situ Treatment)

#### Technology Description

Chemical Waste Management's (CWM) DeChlor/KGME process involves the dechlorination of liquid-phase halogenated compounds, particularly polychlorinated biphenyls (PCB). KGME, a CWM proprietary reagent, is the active species in a nucleophilic substitution reaction, in which the chlorine atoms on the halogenated compounds are replaced with fragments of the reagent. The products of the reaction are a substituted aromatic compound, which is no longer a PCB aroclor, and an inorganic chloride salt.

KGME is the potassium derivative of 2-methoxyethanol (glyme) and is generated in situ by adding stoichiometric quantities of potassium hydroxide (KOH) and glyme. The KOH and glyme are added to the a reactor vessel, along with the contaminated waste. The KGME is formed by slowly raising the temperature of the reaction mixture to about 110°C (230°F), although higher temperature can be beneficial.

The nucleophilic substitution reaction that takes place in the reactor vessel is summarized by the following generalized equation:



where  $\text{Ph}_2\text{Cl}_n$  is a PCB ( $n = 1$  to 10),  $\text{CH}_3\text{OCH}_2\text{CH}_2\text{OK}$  is the KGME reagent,  $m$  is the number of substitutions (from 1 to 10), and  $\text{Ph}_2\text{Cl}_{n-m}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_m$  is the product of the treatment process. A similar mechanism is involved in the KPEG (or APEG) technology, in which the nucleophile is the anion formed by the removal of one terminal hydrogen molecule from a molecule of PEG 440, that is,  $\text{H}(\text{OCH}_2\text{CH}_2)_n\text{O}^-$ .

The DeChlor/KGME technology is preferable to the older sodium (Na) dispersion treatment method because it is less expensive and because the KGME reagent is much more tolerant of water in the reaction mixture; the water can cause a fire or explosion in the presence of Na metal. One advantage of the DeChlor/KGME process over KPEG or APEG methods is that only about one-quarter the weight of KGME is required for dehalogenation as would be required if KPEG were used. Also, considerably less waste is produced, and no polymeric treatment residue, which is difficult to handle, is formed.

The reaction product mixture is a fairly viscous solution containing reaction products and the unreacted excess reagent. After this mixture has cooled to about 93°C (200°F), water is added to help quench the reaction, improve the handling of the mixture, extract the inorganic salts from the organic phase for disposal purposes, and help clean out the reaction vessel for the next batch of material to be treated. The two resulting phases, aqueous and organic, are separated, analyzed, and transferred to separate storage tanks, where they are held until disposal.

The DeChlor/KGME process is applicable to liquid-phase halogenated aromatic compounds, including PCBs, chlorobenzenes, polychlorinated dibenzodioxins (PCDD), and polychlorinated dibenzofurans (PCDF). Waste streams containing less than 1 ppm PCBs to 100 percent aroclors can be treated. Laboratory tests have shown destruction removal efficiencies greater than 99.98 percent for materials containing 220,000 ppm PCBs.



This process is also applicable to the liquid-phase treatment of halogenated aliphatic compounds and has been successfully used for the treatment of contaminated soils on the laboratory scale. Pilot-scale equipment for the treatment of solid materials using this process is in the development stage.

### Technology Performance

A SITE demonstration of this process at the Resolve Superfund site in Massachusetts is scheduled for 1992.

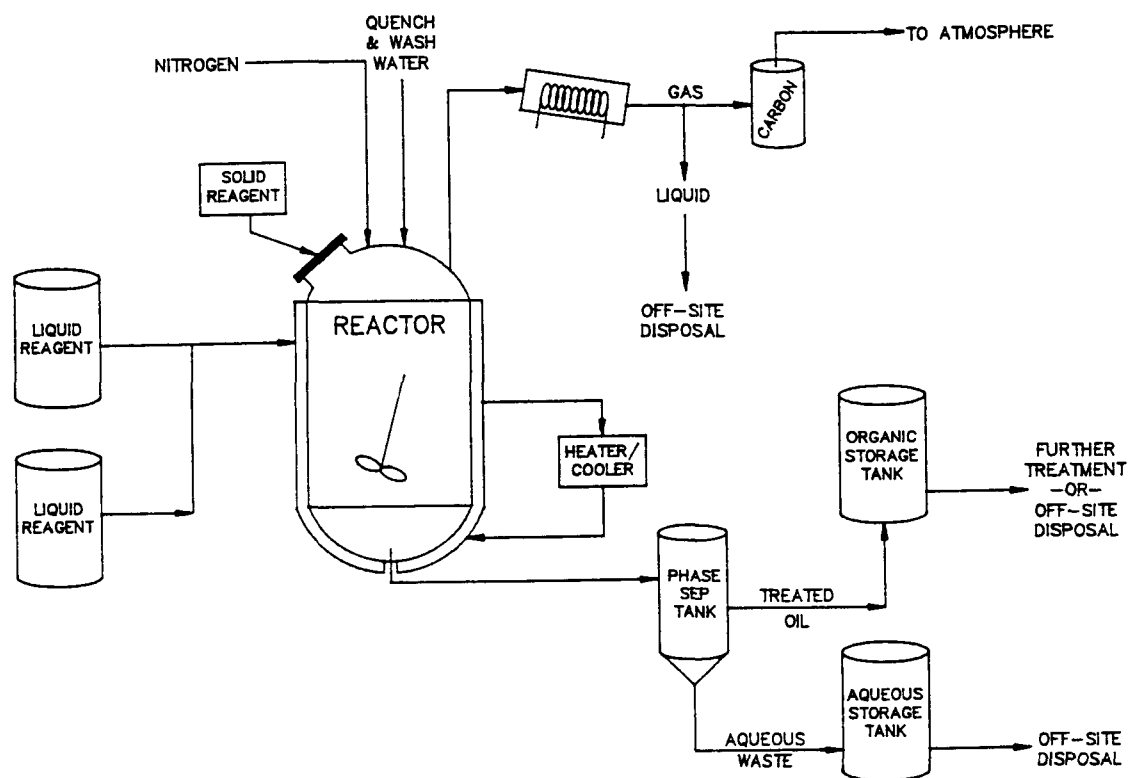
### Remediation Costs

No cost information is available.

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DeChlor/KGME process diagram



## Particle Separation Process PCB and Metals in Sediments

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### Technology Description

This process is used to separate PCB- and metal-laden sediment particles from clean, coarse-grained material. The sediment washing system, developed by Bergmann USA, uses hydroclones, agitation scrubbers, dense media separators, and screens to separate sediments into different solids streams. Bioremediation is used as a secondary treatment for PCBs in the fine-grained fraction. The process is used to reduce the amount of contaminated material requiring disposal. Preliminary tests under the auspices of EPA and the U.S. Department of Interior, Bureau of Reclamation, indicated the use of hydroclones could reduce the amount of material that requires further treatment or disposal by 80 percent. Forced cold-weather shut-down is a limitation in the system.

### Technology Performance

A pilot-scale, on-site demonstration began in October 1991 at the U.S. Army Corps of Engineers, Saginaw Bay Confined Disposal Facility (CDF) in Bay City, Michigan, and was completed in June 1992. The demonstration was part of the Assessment and Remediation of Contaminated Sediments (ARCS) Program authorized by the Water Quality Act of 1987.

Approximately 30 cubic yards of sediments dredged from the Saginaw River was treated each day during the demonstration. Contaminants and grain size was monitored at 23 points in the process.

### Remediation Costs

Remediation costs of using mineral processing separations on contaminated sediment will vary depending on the size of the project, its location, the complexity of the flow sheet, and the water content of the sediment. When the processing techniques are applied in the mining industry, the cost is usually no more than a few dollars per cubic yard. Differences in scale, complexity, and effluent treatment requirements may drive remediation costs into the range of \$20 to \$70 per cubic yard.

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## **perox-pure™**

### **Fuel Hydrocarbons, Chlorinated Solvents, and PCBs in Ground Water**

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#### **Technology Description**

The perox-pure™ technology is designed to destroy dissolved organic contaminants in ground water or wastewater through an advanced chemical oxidation process using ultraviolet (UV) radiation and hydrogen peroxide. Hydrogen peroxide is added to the contaminated water, and the mixture is then fed into the treatment system. The treatment system contains four or more compartments in the oxidation chamber. Each compartment contains one high intensity UV lamp mounted in a quartz sleeve. The contaminated water flows in the space between the chamber wall and the quartz tube in which each UV lamp is mounted.

UV light catalyzes the chemical oxidation of the organic contaminants in water by its combined effect upon the organics and its reaction with hydrogen peroxide. First, many organic contaminants that absorb UV light may undergo a change in their chemical structure or may become more reactive with chemical oxidants. Second, and more importantly, UV light catalyzes the breakdown of hydrogen peroxide to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with organic contaminants, destroying them and producing harmless by-products, such as carbon dioxide, halides, and water. The process produces no hazardous by-products or air emissions.

This technology treats ground water and wastewater contaminated with chlorinated solvents, pesticides, polychlorinated biphenyls (PCB),

phenolics, fuel hydrocarbons (FHC), and other toxic compounds at concentrations ranging from a few thousand milligrams per liter to one microgram per liter. In cases where the contaminant concentration is greater than the technology alone can handle, the process can be combined with other processes such as air stripping, steam stripping, or biological treatment for optimal treatment results.

#### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration at the Lawrence Livermore National Laboratory (LLNL) Superfund site is scheduled for early 1992. This technology has been successfully applied to over 40 different waters throughout the United States, Canada, and Europe, including National Priorities List, Resource Conservation and Recovery Act (RCRA), Department of Energy, and Department of Defense sites. These units are treating contaminated ground water, industrial wastewater, landfill leachates, potable water, and industrial reuse streams.

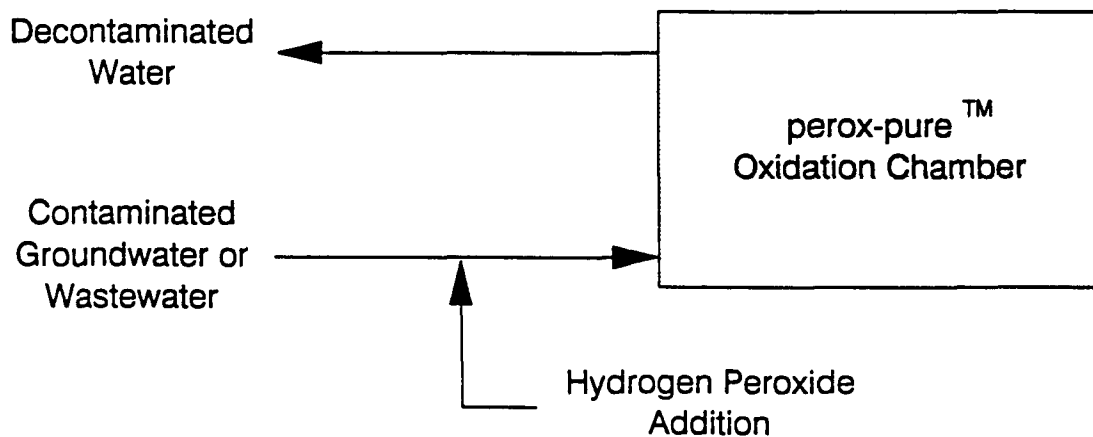
#### **Remediation Costs**

No cost information is available.

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perox-pure™ chemical oxidation technology



## **Photolytic Oxidation Process**

### **Fuel Hydrocarbons in Ground water**

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#### **Technology Description**

This technology is designed to destroy organic contaminants dissolved in water through an advanced chemical oxidation process using ultraviolet (UV) radiation, hydrogen peroxide, and a proprietary catalyst. Contaminated water is fed into the system, and hydrogen peroxide and the proprietary catalyst are added. The mixture is then pumped to the treatment system consisting of six reactor tanks, where the actual destruction of the organic contaminants takes place. Each reactor tank houses a xenon UV lamp mounted in a quartz sleeve. The water flows in the space between the chamber wall and the quartz tube in which each lamp is mounted.

The UV lamps serve two purposes. First, the combination of UV light and hydrogen peroxide produces hydroxyl radicals, which are powerful chemical oxidants. The hydroxyl radicals oxidize organic contaminants, producing harmless by-products, such as carbon dioxide, salts, and water. Second, the UV light can directly break the molecular bonds of the contaminants, further enhancing the oxidation process.

An advantage of the technology is its ability to shift the UV spectral output to closely match the absorption characteristics of the contaminants of concern. By controlling the output of the xenon UV lamps, the technology maximizes contaminant destruction efficiency. The Purus process produces no hazardous by-products or air emissions. The technology is also equipped with safety alarms and an automatic shutdown device in case an emergency should arise.

This technology treats ground water contaminated with fuel hydrocarbons at concentrations up to a few thousand milligrams per liter. The technology can be combined with other processes such as air stripping, steam stripping, or biological treatment for optimal results.

#### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in July 1991. The demonstration at the Lawrence Livermore National Laboratory (LLNL) Superfund site was scheduled for January 1992. The treatment system was to be tested initially at several operating conditions, followed by three reproducibility runs performed at the best operating conditions. When the best operating conditions were determined, more extensive sampling were to be performed.

A bench-scale treatability study of the technology was recently performed at the LLNL Superfund site. Overall, the Purus Model 1000-4 performed as expected during the study. Benzene, toluene, ethylbenzene, and xylene destruction efficiencies averaged about 99 percent.

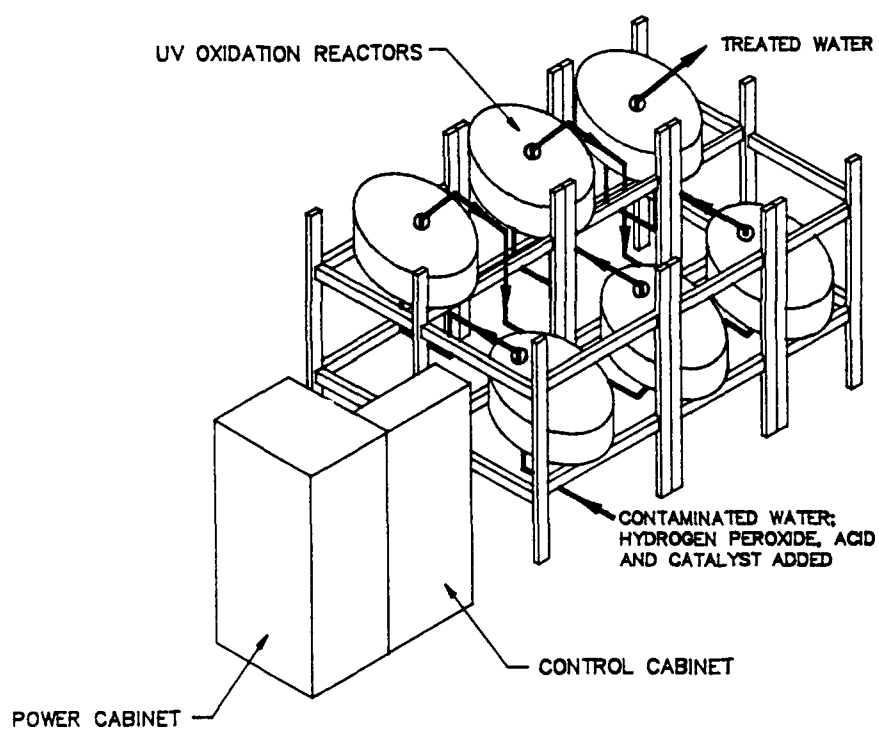
#### **Remediation Costs**

No cost information is available.

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Purus Ultraviolet Oxidation Technology



## Physical Separation/Chemical Extraction Radionuclides and Metals in Sediments

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### Technology Description

In this process sediment is screened, classified and ground, then put into a leaching unit using nitric or hydrochloric acid. Contaminants — cesium-137, cobalt-60, and chromium — are removed from the leachate using a system of ion exchange, precipitation, or evaporation.

The process produces sludge from the leaching system, large-grained material from the screening plant, and ion exchange resin. Ultimate disposal options include calcining leachate and storage of residuals.

### Technology Performance

A pilot-scale test of the process is underway at the U.S. Department of Energy's Idaho National Engineering Laboratory (INEL), a Superfund site. Bench-scale testing was completed at INEL early in 1992, and full-scale remediation using the process is scheduled to begin in November 1992 under a Record of Decision signed in December 1991.

### Remediation Costs

The cost for using this process is about \$30 per cubic yard. Total cost of the INEL remediation project is estimated at \$7.5 million. Design required nine months at an estimated cost of \$500,000. Overall operation and maintenance for the project will require one year.

### General Site Information

The contaminated area is a warm waste pond at the INEL test reactor area, formerly used for testing of materials used in nuclear reactors. INEL is located in Idaho Falls, Idaho.

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## **PO\*WW\*ER™ Evaporation and Catalytic Oxidation**

### **VOCs and Non-volatile Organic Compounds in Ground water**

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#### **Technology Description**

PO\*WW\*ER™ is a technology developed to treat wastewaters, such as leachates, ground waters, and process waters, containing mixtures of salts, metals, and organic compounds. The proprietary technology is a combination of evaporation and catalytic oxidation processes. Wastewater is concentrated in an evaporator by boiling off most of the water and the volatile contaminants, both organic and inorganic. Air or oxygen is added to the vapor, and the mixture is forced through a catalyst bed, where the organic and inorganic compounds are oxidized. This stream, composed of mainly steam, passes through a scrubber, if necessary, to remove any acid gases formed during oxidation. The stream is then condensed or vented to the atmosphere. The resulting brine solution is either disposed of or treated further, depending on the nature of the waste.

The PO\*WW\*ER™ technology can be used to treat complex wastewaters that contain volatile and nonvolatile organic compounds, salts, metals, and volatile inorganic compounds. Suitable wastes include leachates, contaminated ground waters, and process waters. The system can be designed for any capacity, depending on the application and the volume of the wastewater. Typical commercial systems range from 10 to 1,000 gallons per minute (gpm).

#### **Technology Performance**

The PO\*WW\*ER™ technology is currently being tested on landfill leachates, process wastewaters, and other aqueous wastes at the developer's Lake Charles, Louisiana, facility. The pilot plant (capacity, 0.25 gpm) has been in operation since 1988; 20 pilot-scale demonstrations have been completed. A commercial

system (50 gpm) is currently being built by Waste Management International, Inc., at its Hong Kong Chemical Waste Treatment Facility. The SITE program is determining which site to use for evaluating the technology.

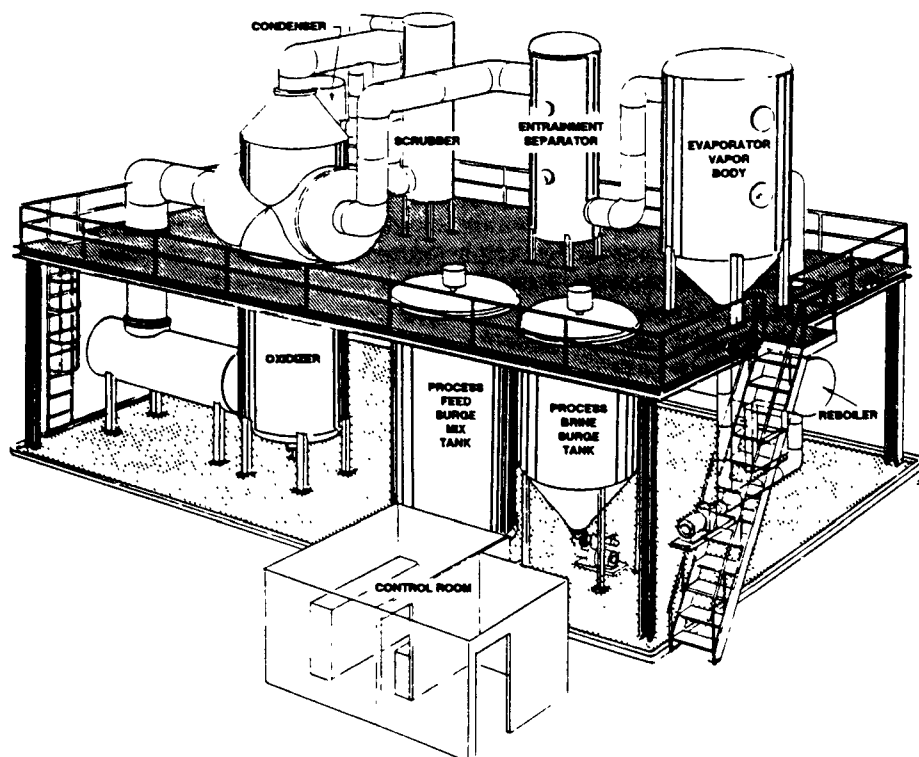
#### **Remediation Costs**

No cost information is available.

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Schematic of PO\*WW\*ER® technology



## Solar Detoxification VOCs in Ground water

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### Technology Description

This technology exposes VOCs in ground water to sunlight in the presence of a non-toxic catalyst ( $\text{TiO}_2$ ) causing the VOCs to break down into non-toxic compounds, such as carbon dioxide, chloride ions, and water.

The process involves a system consisting of a pumping station, a set of solar reflectors, and the reactors, which are narrow Pyrex pipes that hold the contaminated water and the catalyst. During operation, contaminated water is drawn into the pumping station where the flow rate through the solar detoxification system is adjusted, the pH is lowered, and the catalyst is added. The solar reflectors concentrate the sun's light, focus it directly on the Pyrex reactors, and oxidize the VOCs. After moving through the reactors, the water is cooled and its pH is readjusted as necessary. At this point, based on monitoring results, the ground water can be recirculated through the system or the catalyst can be filtered out and the water sent on for secondary treatment for legal discharge to the environment within permitted levels.

### Technology Performance

This system was field tested at Lawrence Livermore National Laboratory in California in 1991. The project clearly demonstrated the destruction of TCE-contaminated ground water to non-detectable levels. While the demonstration did not require full capacity, the system used was capable of treating more than 7,000 gallons per day.

About 200 lbs of used  $\text{TiO}_2$ , containing 2 ppm chromium, was produced during treatment of some 50,000 gallons of ground water. Due to

the chromium content, this would require further treatment as a hazardous waste.

While there were few operational problems, the test confirmed that salts in ground water (chlorides, nitrates, bicarbonates) absorb UV photons and hydroxyl radicals, which can reduce process efficiency.

### Remediation Costs

No cost information available.

### General Site Information

The field demonstration was conducted at Lawrence Livermore National Laboratory (LLNL), Livermore, California. During World War II, LLNL was the site of a naval air station with responsibilities for training and aircraft maintenance. At that time, TCE and other VOCs were used to clean engine parts, and large quantities of these compounds found their way into the ground water beneath the site.

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## **Xanthate Treatment**

### **Heavy Metals in Ground water and Wastewater**

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#### **Technology Description**

This is a process in which metals are removed through precipitation. Metal contaminants in the water exchange with  $\text{Na}^+$  ions contained by the xanthated material to form an insoluble complex. The heavy metals-laden material can then be removed from solution by sedimentation and filtration.

Currently, hydroxide precipitation is used extensively in the treatment of heavy metal-contaminated ground waters and wastewater. Xanthate treatment offers many advantages over hydroxide precipitation, including the following:

- A higher degree of metal removal;
- Less sensitivity to pH fluctuation (metal xanthates do not exhibit amphoteric solubilities);
- Less sensitivity to the presence of complexing agents;
- Improved sludge dewatering properties; and

- The capability of the selective removal of metals.

#### **Technology Performance**

The U.S. Army Engineer Waterways Experiment Station (WES) has performed bench- and pilot-scale treatability studies on xanthate precipitation. Studies are currently being conducted to evaluate the use of xanthates for metal segregation and recycling.

#### **Remediation Costs**

Costs will vary with application, but treatment costs should be similar to currently used precipitation methods.

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## **Thermal Treatment**



## **Anaerobic Thermal Processor**

### **PCBs, Chlorinated Pesticides, and VOCs in Soil and Refinery Wastes**

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#### **Technology Description**

The SoilTech anaerobic thermal processor (ATP) is a thermal desorption process. It heats and mixes contaminated soils, sludges, and liquids in a special rotary kiln that uses indirect heat for processing. The unit desorbs, collects, and recondenses hydrocarbons from solids. The unit also can be used in conjunction with a dehalogenation process to destroy halogenated hydrocarbons through a thermal and chemical process.

The kiln portion of the system contains four separate internal thermal zones: preheat, retort, combustion, and cooling. In the preheat zone, water and volatile organic compounds vaporize. The vaporized contaminants and water are removed by vacuum to a preheat vapor cooling system consisting of a cyclone to remove solids and a heat exchanger and separator to condense liquids and separate the aqueous oil and non-condensable gas phases.

From the preheat zone, the hot granular solids and un-vaporized hydrocarbons pass through a sand seal to the retort zone. Heavy oils vaporize in the retort zone, and thermal cracking of hydrocarbons forms coke and low molecular weight gases. The vaporized contaminants are removed by vacuum to a retort gas handling system. After cyclones remove dust from gases, the gases are cooled, and condensed oil is separated into its various fractions. The coked soil passes through a second sand seal from the retort zone to the combustion zone. Coke is burned and the hot soil is either recycled back to the retort zone or sent to the cooling zone. Flue gases from the combustion zone are treated prior to discharge. The flue gas treatment system consists of the following units set up in series: (1) cyclone and baghouse for particle removal, (2) wet scrubber for removal of acid

gases, and (3) carbon adsorption bed for removal of trace organic compounds.

The combusted soil that enters the cooling zone is cooled in the annular space between the outside of the preheat and retort zones and the outer shell of the kiln. Here, the heat from the soils is transferred to the soils in the retort and preheat zones. The cooled treated soil and coke exiting the cooling zone is quenched with water, then transported by conveyor to a storage pile.

When the ATP is used to dechlorinate contaminants, the contaminated soils are sprayed with an oil mixture containing an alkaline reagent and polyethylene glycol, or other reagents. The oil acts as a carrier for the dehalogenation reagents. In the unit, the reagents dehalogenate or chemically break down chlorinated compounds, including polychlorinated biphenyls (PCB).

The technology can be used for (1) oil recovery from tar sands and shales, (2) dechlorination of PCBs and chlorinated pesticides in soils and sludges, (3) separation of oils and water from refinery wastes and spills, and (4) general removal of hazardous organic compounds from soils and sludges.

#### **Technology Performance**

This technology was accepted into the EPA SITE Demonstration Program in March 1991. Demonstrations, using a full-scale unit, were conducted at the Wide Beach Development Superfund site in Brant, New York, in 1991 and at the Outboard Marine Corporation site in Waukegan, Illinois, in 1992.

The preliminary test results from the 1991 demonstration indicated that:

- The SoilTech ATP unit removed over 99 percent of the PCBs in the contaminated soil, resulting in PCB levels below the desired cleanup concentration of 2 parts per million (ppm).
- The SoilTech ATP does not appear to create dioxins or furans.
- No volatile or semivolatile organic degradation products were detected in the treated soil. There were also no leachable volatile organic compounds (VOC) or semivolatile organic compounds (SVOC) detected in the treated soil.
- No operational problems affecting the ATP's ability to treat the contaminated soil were observed.

## Remediation Costs

No cost information is available.

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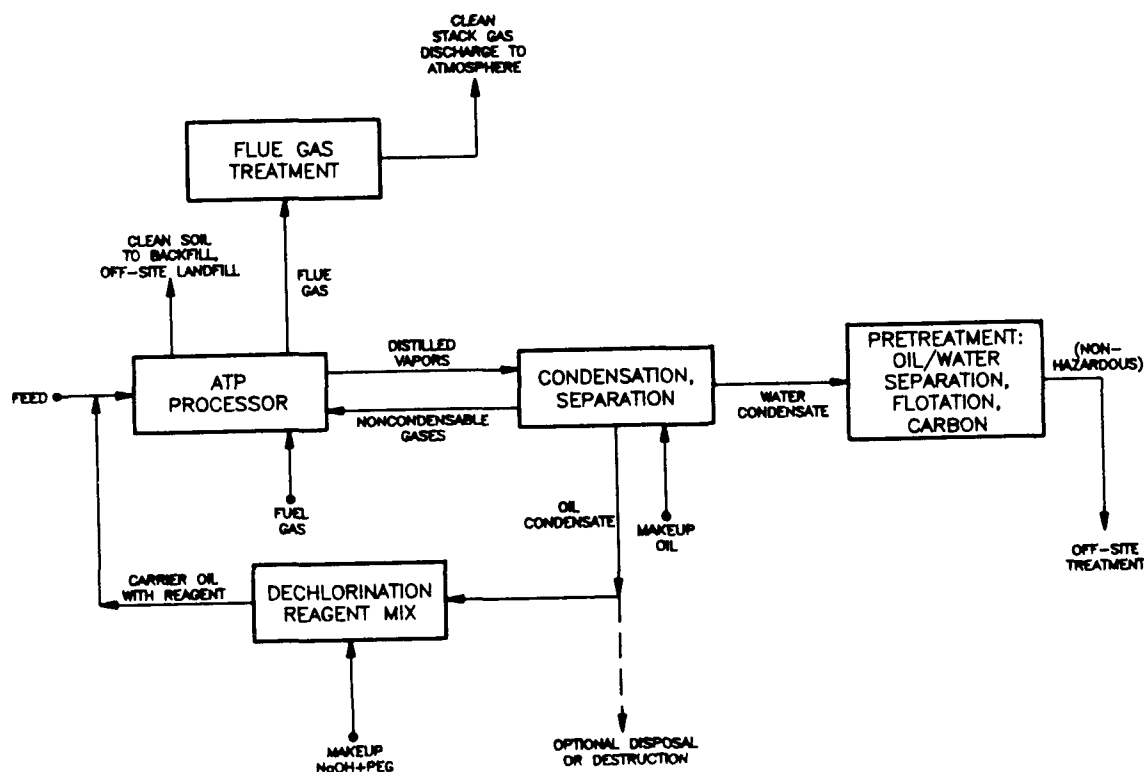
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Schematic diagram of the ATP process



## **Cyclone Furnace Organics and Metals in Soil**

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### **Technology Description**

This furnace technology is designed to decontaminate wastes containing both organic and metal contaminants. The cyclone furnace retains heavy metals in a non-leachable slag and vaporizes and incinerates the organic materials in the wastes.

The treated soils resemble natural obsidian (volcanic glass), similar to the final product from vitrification.

The furnace is a horizontal cylinder and is designed for heat release rates greater than 450,000 Btu per cubic foot (coal) and gas temperatures exceeding 3,000°F. Natural gas and preheated primary combustion air (820°F) enter the furnace tangentially. Secondary air (820°F), natural gas, and the synthetic soil matrix (SSM) enter tangentially along the cyclone barrel (secondary air inlet location). The resulting swirling action efficiently mixes air and fuel and increases combustion gas residence time. Dry SSM has been tested at pilot-scale feed rates of both 50 and 200 lb/hr. The SSM is retained on the furnace wall by centrifugal action; it melts and captures a portion of the heavy metals. The organics are destroyed in the molten slag layer. The slag exits the cyclone furnace (slag temperature at this location is 2,400°F) and is dropped into a water-filled slag tank where it solidifies into a non-leachable vitrified material. A small quantity of the soil also exits as fly ash from the furnace and is collected in a baghouse.

This technology may be applied to high-ash solids (such as sludges and sediments) and soils containing volatile and nonvolatile organics and heavy metals. The less volatile metals are captured in the slag more readily. The technology would be well-suited to mixed waste soils contaminated with organics and non-volatile radionuclides (such as plutonium, thorium, uranium). Because vitrification has been listed as Best Demonstrated Achievable Technology (BDAT) for arsenic and selenium wastes, the cyclone furnace may be applicable to these wastes.

### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in August 1991. The demonstration will be conducted at the developer's facility in winter 1991 using synthetic soil matrices spiked with heavy metals, semivolatile organics, and radionuclide surrogates.

### **Remediation Costs**

No cost information is available.

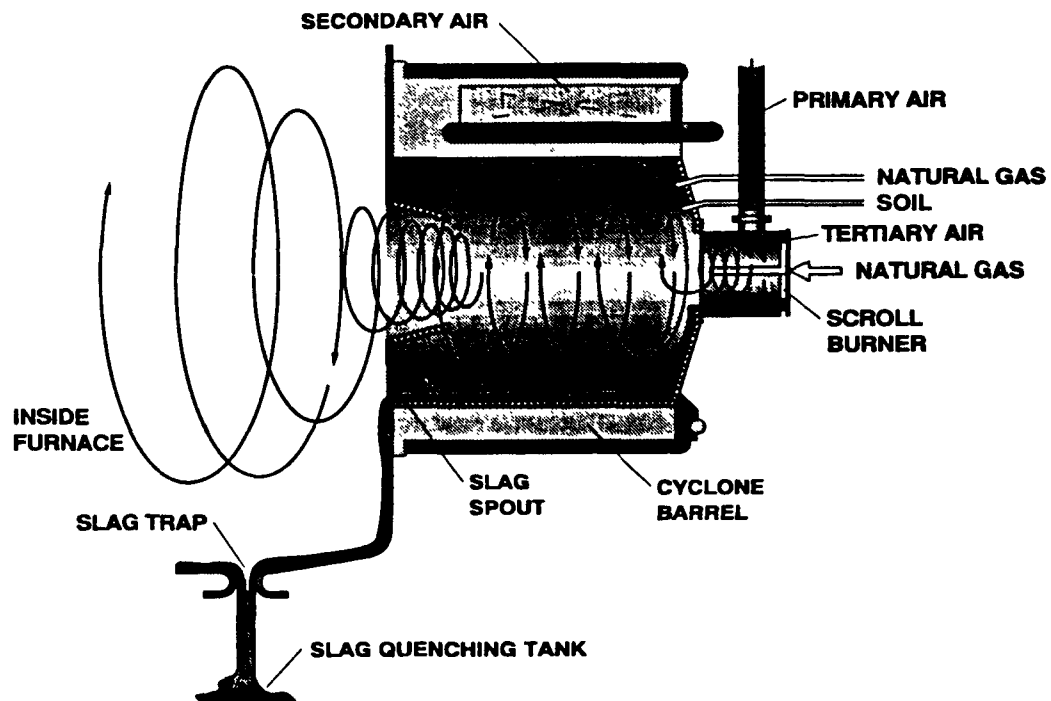


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Cyclone furnace



## **Desorption and Vapor Extraction System**

### **VOCs, Semi-VOCs, and Volatile Inorganics in Soil and Sediment**

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#### **Technology Description**

The mobile, high-capacity (10.5 to 73 tons per hour capacity with 85 percent solids) desorption and vapor extraction system (DAVES) uses a low-temperature fluidized bed to remove organic and volatile inorganic compounds from soils, sediments, and sludges. Contaminated materials are fed into a co-current, fluidized bed, where they are mixed with hot air (about 1,000°F to 1,400°F) from a gas-fired heater. Direct contact between the waste material and the hot air forces water and contaminants from the waste into the gas stream at a relatively low fluidized-bed temperature (about 320°F). The heated air, vaporized water and organics, and entrained particles flow out of the dryer to a gas treatment system. The gas treatment system removes solid particles, vaporized water, and organic vapors from the air stream. A cyclone separator and baghouse remove most of the particulates in the gas stream from the dryer. Vapors from the cyclone separator are cooled in a venturi scrubber, counter-current washer, and chiller section, before they are treated in a vapor-phase carbon adsorption system. The liquid residues from the system are centrifuged, filtered, and passed through two activated carbon beds arranged in series.

By-products from the DAVES include (1) approximately 96 to 98 percent of solid waste feed as treated, dry solid, (2) a small quantity of centrifuge sludge containing organics, (3) a small quantity of spent adsorbent carbon, (4) wastewater that may need further treatment, and (5) small quantities of baghouse and cyclone dust that are recycled back through the process.

The centrifuge sludge containing organics can be bioremediated, chemically degraded, or treated in another manner. Recycling Sciences

International, Inc., is currently working with Argonne National Laboratory on an adjunct electrochemical oxidation process that will enable complete contaminant destruction within the DAVES process.

This technology can remove volatile and semivolatile organics, including polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), pentachlorophenol (PCP), volatile inorganics (such as tetraethyl lead), and some pesticides from soil, sludge, and sediment. In general, the process treats waste containing less than 10 percent total organic contaminants and 30 to 95 percent solids. The presence of non-volatile inorganic contaminants (such as metals) in the waste feed does not inhibit the process; however, these contaminants are not treated.

#### **Technology Performance**

EPA is currently selecting a demonstration site for this process. The wastes preferred for the demonstration are harbor or river sediments containing at least 50 percent solids and contaminated with PCBs and other volatile or semivolatile organics. Soils with these characteristics may also be acceptable. About 300 tons of waste are needed for a 2-week test. Major test objectives are to evaluate feed handling, decontamination of solids, and treatment of gases generated by the process.

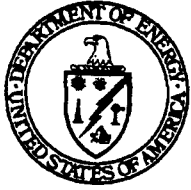
**Remediation Costs**

No cost information is available.

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## **Dynamic Underground Stripping**

### **Organics in Concentrated Underground Plumes (In Situ Treatment)**

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#### **Technology Description**

This technology is used to treat underground leaks of organic contaminants, such as those from underground storage tanks, which can be a source of ground-water contamination. The technology uses large amounts of added energy to speed the contaminant removal process. Because it is a highly energetic process, real-time monitoring is necessary both for process control and to ensure that contaminants are not inadvertently mobilized or moved to unanticipated areas.

Injection wells are installed in permeable areas surrounding the concentrated plume, and one or more extraction wells are installed in the center. The extraction wells are pumped to depress the water table in the center of the pattern. Then, steam is injected at 50 to 60 psi. Injection pressure is controlled by depth, and would be lower in shallow applications.

As the steam is forced into the formation, the earth is heated to the boiling point of water. The advancing pressure front displaces ground water toward the extraction well. Near the steam-condensate front, organics are distilled into the vapor phase, transported to the front, and condensed there. The advancing steam zone displaces the condensed liquids toward the recovery well where they are pumped to the surface.

When the steam reaches the extraction well, vacuum extraction becomes the most important removal mechanism.

At this point in the process, electrode assemblies placed in the impermeable layers are turned on, passing 480 V current at several hundred amperes per electrode. This heats clay and fine-grained sediments, causing any water and contaminants trapped within to vaporize and be forced into the steam zones and toward the extraction well. This heating may be followed by one or more additional steam injection phases, for contaminant removal and to keep permeable zones hot as ground water returns.

#### **Technology Performance**

A demonstration of this technology at a gasoline spill site at Lawrence Livermore National Laboratory (LLNL) in California is being conducted during the current fiscal year. Plans call for six injection wells around the perimeter of the spill zone. Up to three extraction wells are to be used to maintain the high ground water removal rates required.

#### **Remediation Costs**

No cost information is available.

### **General Site Information**

The demonstration of this technology is being conducted at a spill site at LLNL in Livermore, California. Approximately 17,000 gallons of gasoline were spilled at the site. Some 5,000 gallons of the spill are now trapped beneath the water table because of a 30-ft rise in the water table. The remainder of the spill is in the vadose zone.

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## High-Temperature Thermal Processor Organics in Solids and Sludges

### Technology Description

Remediation Technologies, Inc.'s (ReTeC), high temperature thermal processor is a thermal desorption system that can treat solids and sludges contaminated with organic constituents. The system consists of material feed equipment, a thermal processor, a particulate removal system, an indirect condensing system, and activated carbon beds.

Waste from the feed hopper is fed to the thermal processor, which consists of a jacketed trough that houses two intermeshing, counter-rotational screw conveyors. The rotation of the screws moves material through the processor. A molten salt eutectic, consisting primarily of potassium nitrate, serves as the heat transfer media. This salt melt has heat transfer characteristics similar to those of oils and allows maximum processing temperatures of up to 850°F. The salt melt is noncombustible, it poses no risk of explosion, and its potential vapors are nontoxic. The heated transfer media continuously circulates through the hollow flights and shafts of each screw and also circulates through the jacketed trough. An electric or fuel oil/gas-fired heater is used to maintain the temperature of the transfer media. Treated product is cooled to less than 150°F for safe handling.

A particulate removal system (such as a cyclone or quench tower), an indirect condensing system, and activated carbon beds are used to control off-gases. The processor operates under slight negative pressure to exhaust the volatilized constituents (moisture and organics) to the off-gas control system. An inert atmosphere is maintained in the headspace of the processor through the use of air lock devices at the feed inlet and solids exit, and through the

introduction of an inert carrier gas (such as nitrogen) to maintain an oxygen concentration of less than 3 percent. The oxygen and organic content of the off-gas are continuously monitored as it exits the processor.

Entrained particulate matter is collected and combined with the treated solids on a batch basis. The volatilized moisture and organics are subsequently condensed and decanted. A mist eliminator minimizes carry-over of entrained moisture and contaminants after the condenser. Any remaining non-condensable gases are passed through activated carbon beds to control volatile organic compound emissions.

This system can treat soils, sediments, and sludges contaminated with volatile and semivolatile organics, including polychlorinated biphenyls. Preliminary testing indicates the system has the potential to treat cyanide. With the exception of mercury, the process is not suitable for treating heavy metals. Wastes must be prescreened to a particle size of less than 1 inch before treatment.

### Technology Performance

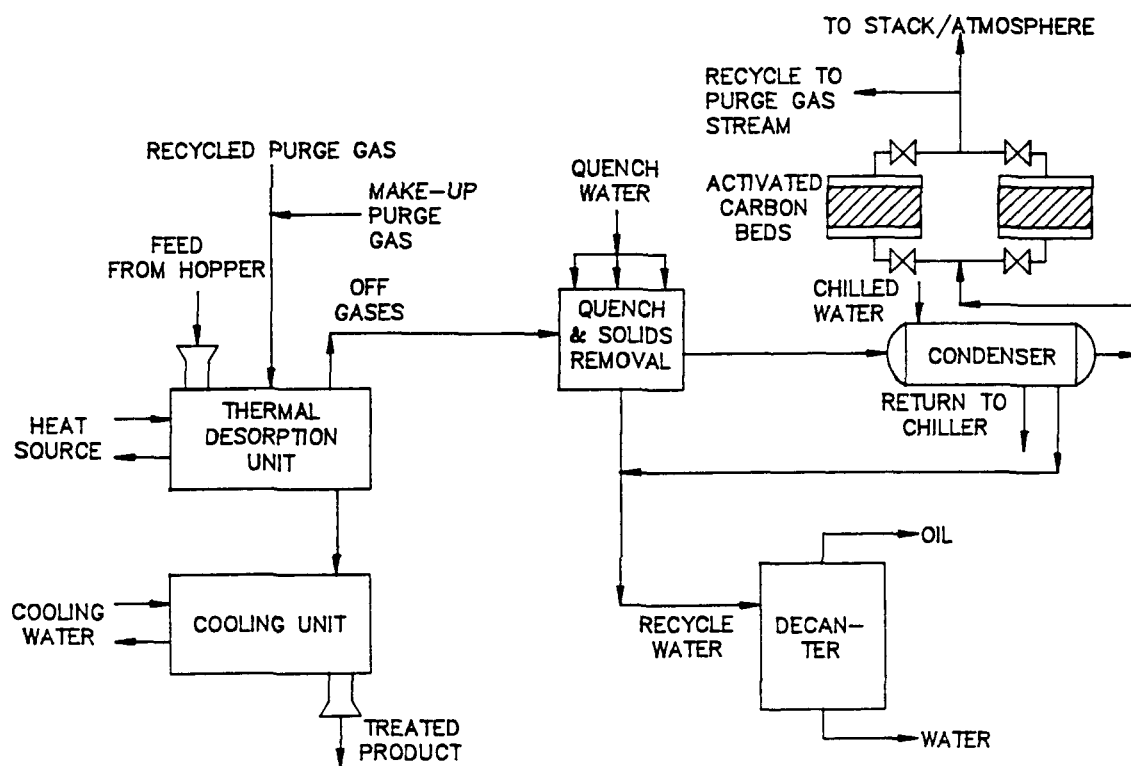
This technology was accepted into the SITE Demonstration Program in June 1991. The SITE demonstration is scheduled for the Niagara-Mohawk Power Company, a manufacturing gas plant site, in Harbour Point, New York, in 1992.

### Remediation Costs

No cost information is available.

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Process flow diagram



## Low-Temperature Thermal Stripping Volatile Organic Compounds in Soil

### Technology Description

Low-temperature thermal stripping of volatile organic compounds (VOC) from soils removes volatile components such as chlorinated solvents and fuels. It can be applied to contaminated soils associated with fire training pits, burn pits, spills, and lagoons. Contaminants having boiling points as high as 500°C have been removed from soils.

In 1985, the U.S. Army Toxic and Hazardous Materials Agency sponsored the development of a Low-Temperature Thermal Stripping process which used a Holo-Flite screw thermal processor. Contaminated soil is fed through an opening at the top of the system, called the soil feed hopper. The soil falls into the main part of the system, or thermal processor. The thermal processor consists of two separate but identical units, each containing four large, hollow screws. The screws are 18 inches in diameter and 20 feet long. As the screws turn, they churn the soil, breaking it up and pushing it from the feed end of the processor to the discharge end.

In the meantime, hot oil is pumped through the inside of the screws. The constant churning of the soil and movement of hot oil up and down the length of the screws heat the soil and volatilize the VOCs. Additional heat is provided by the walls of the processor, called the trough jacket, which also contains flowing hot oil. The thermal processor heats up to a maximum of about 650°F.

This method does, however, have a number of limitations: this is a media transfer technique rather than a destructive technique; treatment of the gaseous effluent prior to discharge might be required, depending upon local regulations; bench-scale evaluation should be conducted before pilot testing or implementation; the

equipment for the bench-scale test is available and will fit in a standard laboratory hood; lower explosive limits must be considered when treating soils contaminated with flammable solvents; an inert gas such as nitrogen might be considered as an alternative to air to reduce the risk of combustion or explosion; and since this is a low-temperature method, metal contaminants will not be removed.

### Technology Performance

The results from a pilot-scale field demonstration of this technology were extremely positive. Eighteen days of formal testing were completed in 22 consecutive calendar days. During this period, more than 10,000 pounds of contaminated soils were processed. Upon completion of the formal testing, 10 additional days of testing were conducted to optimize system performance. During this period, more than 5,000 pounds of contaminated soils were processed. A comparison of the VOCs measured in the processed soil and stack gas indicated that a greater than 99.9 percent destruction and removal efficiency was achieved. A summary of the soil concentrations and maximum VOC removal efficiencies is provided in Table 1. Stack emissions were in compliance with all Federal and state regulations (including VOCs, HCL, CO, and particulate). After processing, regulatory approval was granted to dispose of the treated soils on site as backfill.

### Remediation Costs

To treat a site containing 15,000 to 80,000 tons of contaminated soil, the optimally-sized process costs would range from \$74 per ton to \$160 per ton, respectively, without flue gas treatment. If



afterburner exhaust gases are treated prior to discharge, the respective costs range from \$87 per ton to \$184 per ton.

#### **General Site Information**

A large-scale pilot test was conducted at Letterkenny Army Depot, Chambersburg, Pennsylvania. The demonstration was conducted between August 5 and September 16, 1985. The feed soils were excavated from lagoons in the K-1 Area which received organic liquids from industrial operations at the Depot. The contaminants were trichloroethylene, dichloroethylene, tetrachloroethylene, and xylene.

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Table 1. Summary of Soil VOC Concentrations and Maximum VOC Removal Efficiencies			
VOC	Feed Soil Average (ppm)	Concentrations Maximum (ppm)	Maximum Removal Efficiency
Dichloroethylene	83	470	>99.9
Trichloroethylene	1,673	19,000	>99.9
Tetrachloroethylene	429	2,500	>99.9
Xylene*	64	380	>99.9
Other VOCs	14	88	>99.9
Total VOCs	2,263	22,438	>99.9
* Xylene is not classified as a VOC since its boiling point is approximately 140°C. However, it was included in this study to evaluate the effectiveness of this technology on higher boiling point semivolatile compounds.			



## Low-Temperature Thermal Treatment (LT<sup>3</sup>) Volatile and Semivolatile Organics in Soil

### Technology Description

The basis of the LT<sup>3</sup> technology is the thermal processor, an indirect heat exchanger used to dry and heat contaminated soils. The process includes three main steps: soil treatment, emissions control, and water treatment. Equipment used in the process is mounted on three tractor trailer beds for transport and operation. Excavated soil is processed through a shredder to increase the surface area of the soil. (This step may not be needed for sludges or similar matrices.) The conveyor and surge hopper, which are enclosed to reduce emissions, then feed the soil into the thermal processor. The thermal processor consists of two covered troughs that house four intermeshed screw conveyors. The covered troughs and screws are hollow to allow circulation of hot oil, providing indirect heating of the soils. Each screw moves the soil through the processor and thoroughly mixes the material.

The heating of the soil to 400°F to 500°F evaporates contaminants from the soil. (Temperatures may vary depending on the specific contaminants of concern.) The vapor stream is then processed through a baghouse dust collector, two condensers in series, and is subsequently treated by carbon adsorption to remove about 99 percent of the organic contaminants and any particulate emissions. Remaining exhaust gas is continuously monitored to ensure that it contains total organic concentrations not greater than 3 ppm by volume.

The condensate from the LT<sup>3</sup> system is separated into light and heavy organic compounds and water. The water is treated by carbon adsorption until it is free of contaminants, at which time it can be recycled to the fresh water system to be sprayed on the

treated soil for dust control. The spraying occurs in the system before the soil is released. No water is discharged from the LT<sup>3</sup> process.

This technology can be applied to soils contaminated with volatile and semivolatile organic compounds.

### Technology Performance

A full-scale demonstration was conducted at Tinker Air Force Base in Oklahoma City, Oklahoma, in 1989. The demonstration was designed to remove jet propulsion fuel (JP-4) and chlorinated organic compounds, such as TCE, from contaminated soils. The only modification to the basic LT<sup>3</sup> was the addition of a scrubber system to control acid gas emissions.

The demonstration showed conclusively that the LT<sup>3</sup> technology was effective in reducing the concentration of not only JP-4 but also all compounds originally specified in the Test Plan. All goal clean-up levels could be met by heating the processed soil above 215°F. This was a considerably lower temperature than anticipated. As a result, all goal clean-up levels were met while processing soil at rates 25 percent in excess of the design capacity. The treatment capacity was 18,000 to 20,000 lbs per hour.

The demonstration was discontinued when PCBs were discovered in the feed and processed soils, because the system had not been designed to process PCBs.

This technology was accepted into the SITE Demonstration Program in September 1991. The Anderson Development Company (ADC) Superfund site, Adrian, Michigan, was selected as the demonstration site. ADC manufactures

specialty organic chemicals. The demonstration was completed early in 1992, and a report of findings is expected late in the year.

### **Remediation Costs**

Based on the demonstration at Tinker Air Force Base, the unit cost for processing and decontaminating soil with similar contaminants is \$86.00 per ton soil at an average processing rate of 8 tons per hour. Total estimated costs, including mobilization and demobilization, to process 5,000 tons would be \$116.00 per ton. Fixed costs for mobilization, start up, and demobilization would be approximately \$150,000.00.

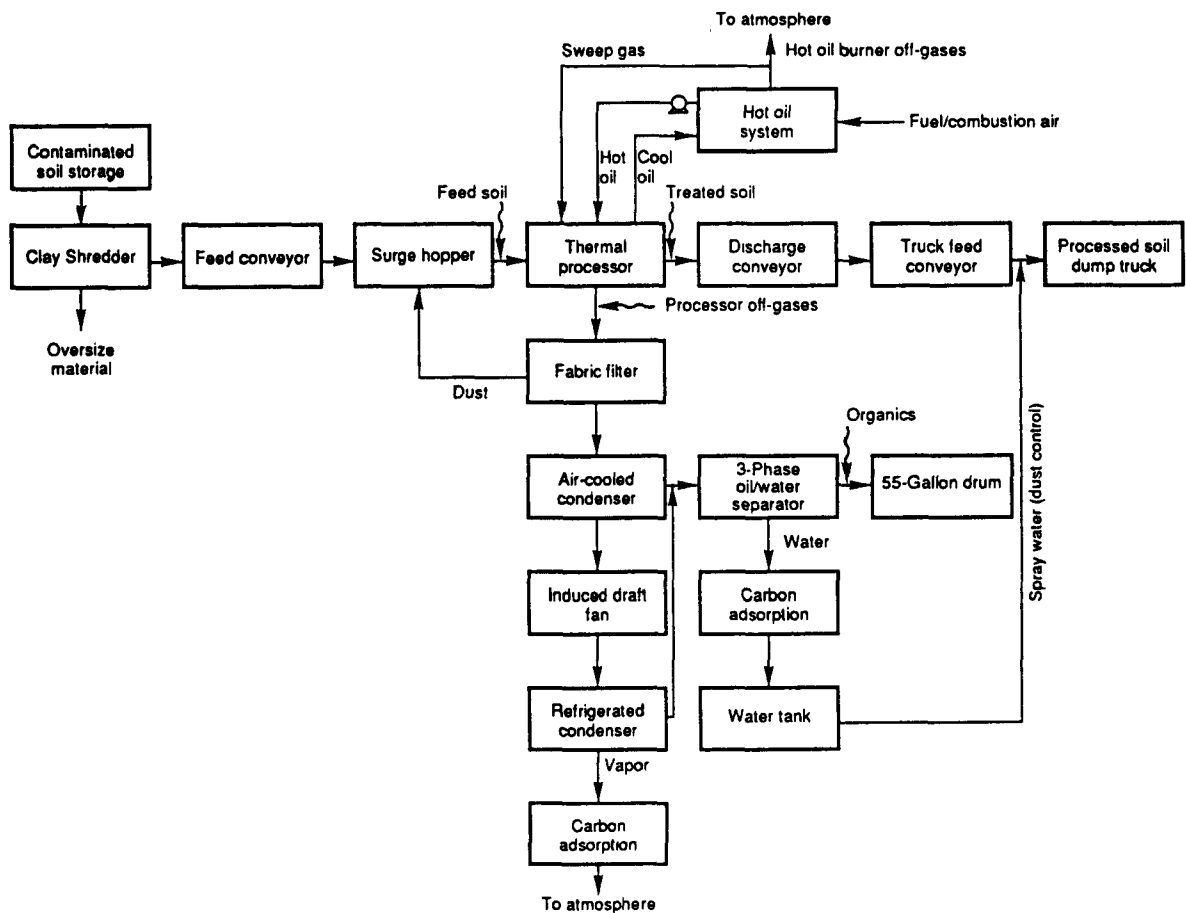
No cost information is available at this time from the SITE Program demonstration in Michigan.

### **Contacts**

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Schematic diagram of the LT<sup>30</sup> system



## **Molten Salt Oxidation Process**

### **Radionuclides, Organics, Oils, Graphite, Chemical Warfare Agents, Explosives in Liquids and Solids**

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#### **Technology Description**

The Molten Salt Oxidation (MSO) Process is carried out in a highly reactive oxidizing and catalytic medium. It uses a sparged bed of turbulent molten salt such as sodium carbonate at 800°C to 1,000°C with waste and air introduced beneath the surface of the molten salt. Generally, the heat of oxidation of the waste keeps the salt molten. The off-gas, containing carbon dioxide, steam, nitrogen, and unreacted oxygen is cleaned of particulates by passing the gas through standard filters before discharging to the atmosphere.

MSO has a high treatment potential for radioactive and hazardous forms of high-heating liquids (organic solvents, waste oils), low-heating value liquids (high-halogen content organic liquids), other wastes (pesticides, herbicides, PCBs, chemical warfare agents, explosives, propellants, infectious wastes), and extraction gases (volatile organic compounds and radionuclides, acids). By virtue of the latter, MSO could replace conventional wet-scrubbers as a superior dry-scrubber system for use with incinerators. The typical residence time is two seconds for the treatment of wastes by the MSO Process.

Aqueous sludges containing heavy metals are converted to oxides and retained in the melt. Organics in addition to combustible solids are destroyed but MSO is not suitable for treatment of inert solids, such as soils. The Process also successfully destroys carbon in coal gasification demonstrations.

Ash and soot reaction products are retained in the molten salt. The MSO Process has been tested at 900°C for the destruction of solid combustible waste bearing plutonium at TRU

levels. Measurable amounts of plutonium downstream of the oxidizer have shown that 99.9 percent of the plutonium remains in the melt.

The final waste form is a product of the spent salt disposal or recycle subsystem. In the destruction of chlorinated waste compounds, the melt becomes unreactive as the salt converts to approximately 90 percent NaCl. The sodium chloride can be discarded unless it is contaminated with radionuclides. These can be extracted from the disposable salt by ion exchange chemistry coupled with biosorption techniques. Otherwise, when the salt is reusable but contains ash, soot, and possibly metal products, conventional dissolution and fractional filtration techniques with radionuclide extraction apply.

#### **Technology Performance**

Fundamental theoretical studies, experimental investigations, and demonstrations were supported by DOE and Rockwell International for about 20 years until 1982 when it was determined that MSO offered no cost advantage over incineration at that time. Prior to 1982, Rockwell had conducted bench-scale unit (10 lb/hr feed rate) tests on chlordane for EPA. Using the Rockwell bench-scale MSO unit, Edgewood Arsenal personnel in 1976 demonstrated the high-efficiency destruction of the chemical warfare agents VX, GB, and mustard. Rockwell conducted tests on a pilot-scale unit (270 lb/hr feed rate) to demonstrate the destruction of hazardous chemicals such as PCB for the Canadian Electric Association and, again, EPA. The largest Rockwell MSO unit (2,000 lb/hr feed rate) to date was built and

operated for DOE in 1973 to demonstrate MSO as a coal gasification technology.

### **Remediation Costs**

The destruction of VX, GB, and mustard by the MSO Process at the bench-scale level costs \$2.03 per pound today. No firm cost information is available for other applications of MSO as a primary treatment system or as an incinerator off-gas dry-scrubber system. The DOE is currently engaged in a five-year MSO implementation plan which is expected to begin yielding that information.

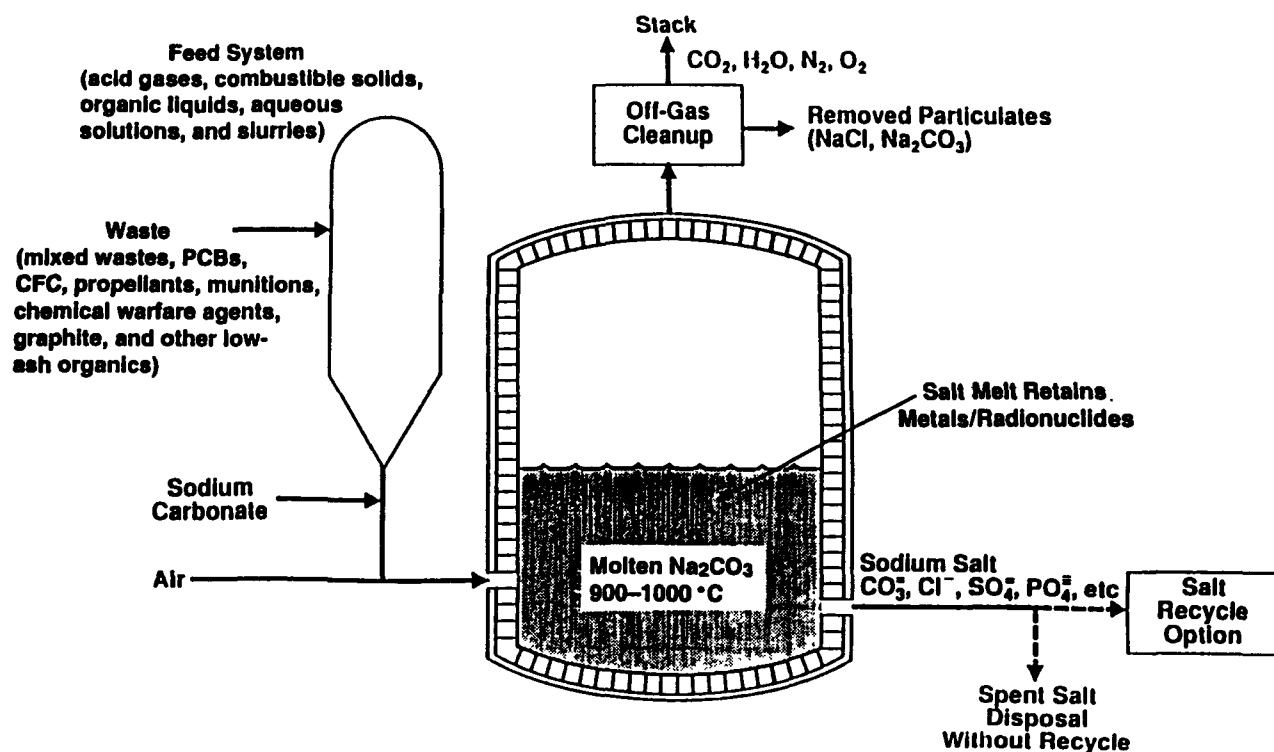
### **General Site Information**

The DOE five-year MSO implementation plan leads to commercial-scale demonstrations of the MSO technology by 1997. Rockwell International is the principal industry partner.

Bench-scale demonstrations of mixed (radioactive and hazardous) waste treatment will be conducted at several DOE installations: Energy Technology Engineering Center; Oak Ridge National Laboratory, and Los Alamos National Laboratory. At EPA's Incinerator Research Facility, a bench-scale-size MSO unit designed to treat a slipstream of the rotary kiln incinerator flue gas (containing radionuclide surrogates and acids) will be operated to evaluate the effectiveness of MSO as a dry-scrubber for controlling gas emissions from incinerators.

### **Contact**

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Washington, DC 20585  
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<b>Chemical (Partial Listing)</b>	<b>Destroyed (%)</b>
<b>PCB</b>	<b>6 - 9's</b>
<b>Para-arsanilic acid</b>	<b>&gt;5 - 9's</b>
<b>Chloroform</b>	<b>&gt;5 - 9's</b>
<b>Trichloroethane</b>	<b>&gt;5 - 9's</b>
<b>Diphenylamine HCl</b>	<b>&gt;5 - 9's</b>
<b>Nitroethane</b>	<b>&gt;4 - 9's</b>
<b>HCB</b>	<b>9 - 9's</b>
<b>Chlordane</b>	<b>7 - 9's</b>
<b>VX</b>	<b>&gt;7 - 9's</b>
<b>GB</b>	<b>&gt;8 - 9's</b>
<b>Mustard</b>	<b>&gt;6 - 9's</b>
<b>HMX (35 wt%)</b>	<b>4 - 9's</b>

The Molten Salt Oxidation (MSO) Process





## **Plasma Arc Vitrification**

### **Organics and Metals in Soils and Sludge**

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#### **Technology Description**

Plasma Arc Vitrification occurs in a plasma centrifugal furnace by a thermal treatment process where heat from a transferred arc plasma creates a molten bath that detoxifies the feed material. Organic contaminants are vaporized and react at temperatures of 2,000°F to 2,500°F to form innocuous products. Solids melt and are vitrified in the molten bath at 2,800°F to 3,000°F. Metals are retained in this phase. When cooled, this phase is a non-leachable, glassy residue which meets the toxicity characteristic leachate procedure (TCLP) criteria.

Contaminated soils enter the sealed furnace through the bulk feeder. The reactor well rotates during waste processing. Centrifugal force created by this rotation prevents material from falling out of the bottom and helps to evenly transfer heat and electrical energy throughout the molten phase. Periodically, a fraction of the molten slag is tapped, falling into the slag chamber to solidify.

Off-gas travels through a secondary combustion chamber where it remains at 2,000°F to 2,500°F for more than 2 seconds. This allows the complete destruction of any organics in the gas. After passing through the secondary combustion chamber, the gases pass through a series of air pollution control devices designed to remove particulates and acid gases. In the event of a process upset, a surge tank allows retention for reprocessing.

Residuals from the cleanup system can sometimes be fed back to the furnace. Salts resulting from neutralizing chlorides must eventually be discarded. In some circumstances, metals can be recovered from the scrubber sludge.

Liquid and solid organic compounds and metals can be treated by this technology. It is most appropriate for chemical plant residues and by-products, low-level mixed radioactive wastes, and contaminated soils. It may also be useful for medical wastes, sewage, sludge, and incinerator ash.

#### **Technology Performance**

The SITE demonstration was conducted in July 1991 at a Department of Energy research facility in Butte, Montana. During the demonstration, the furnace processed approximately 4,000 pounds of waste. All feed and effluent streams were sampled to assess the performance of this technology. A report on the demonstration project will be available in 1992.

A production size furnace has been permitted and commissioned in Muttens, Switzerland. At this installation, the furnace is designed to feed 55-gallon (200-liter) drums. Each drum and its contents are fed and destroyed, one drum at a time.

#### **Remediation Costs**

No cost information is available.

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Technology Developer Contact:

R. C. Eschenbach

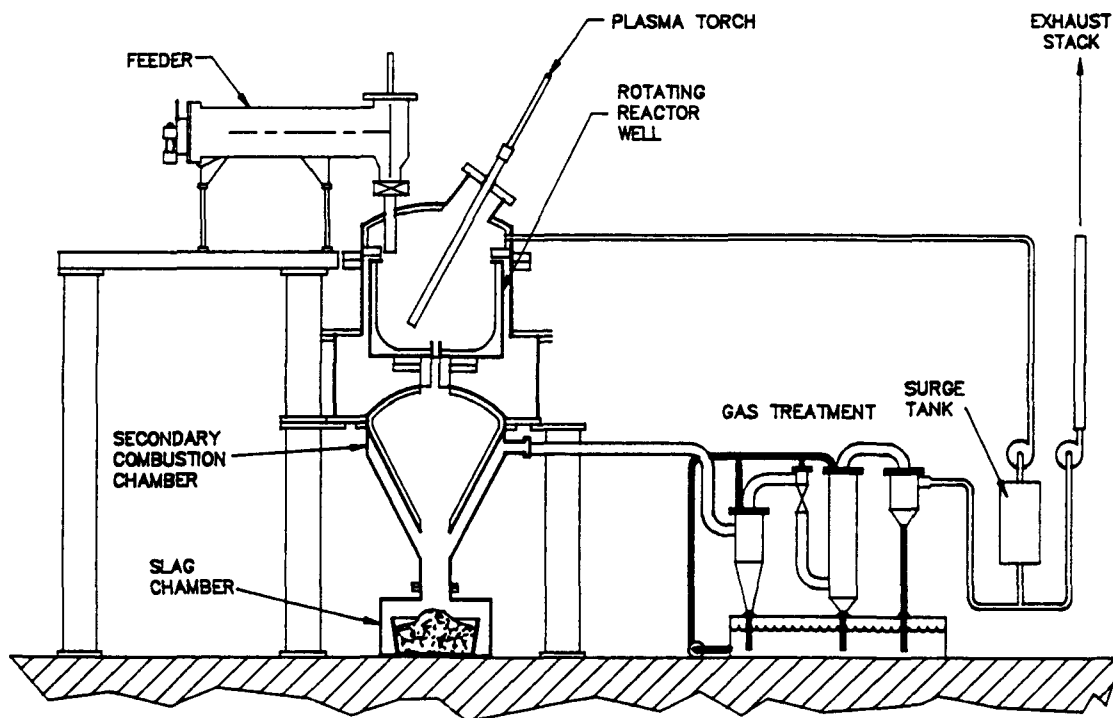
Retech, Inc.

P.O. Box 997

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Ukiah, CA 95482

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Plasma centrifugal furnace



## **Radio Frequency (RF) Thermal Soil Decontamination**

### **Solvents and Volatile and Semivolatile Petroleum in Soils (In Situ Treatment)**

#### **Technology Description**

The radio frequency (RF) thermal soil decontamination process removes volatile hazardous waste materials through in situ radio frequency heating of the soil and volatilization of the hazardous substances. This technology can be applied to fire training pits, spills, and sludge pits containing solvents and volatile and semivolatile petroleum.

Radio frequency heating is performed by the application of electromagnetic energy in the radio frequency band. The energy is delivered by electrodes placed in holes drilled through the soil. The mechanism of heat generation is similar to that of a microwave oven and does not rely on the thermal properties of the soil matrix. The power source for the process is a modified radio transmitter. The exact frequency of operation is selected after evaluation of the dielectric properties of the soil matrix and the size of the area requiring treatment. The gases and vapors formed in the soil matrix can be recovered at the surface or through the electrodes used for the heating process. Condensation and collection of the concentrated vapor stream is used to capture the contaminant above ground. The system is made up of four components: (1) RF energy deposition electrode array; (2) RF power generation, transmission, monitoring, and control system; (3) vapor barrier and containment system; and (4) gas and liquid condensate handling and treatment system.

This technology has a number of advantages:

- Demonstrations have shown higher than 90 percent reduction of jet fuel components from soils;

- Contaminants are recovered in a relatively concentrated form without dilution from large volumes of air or combustion gases;
- This is an in situ method;
- All equipment is portable; and
- The soil does not have to be excavated.

Limitations of this technology include:

- High moisture or presence of ground water in the treatment zone will result in excessive power requirements to heat the soil; and
- The method cannot be used if large buried metal objects are in the treatment zone.

#### **Technology Performance**

The full-scale field demonstration at Volk Field Air National Guard Base, Camp Douglas, Wisconsin, produced positive results:

- 94 to 99 percent decontamination of a 500 cubic feet block of soil was achieved during a 12-day period. Ninety-seven percent of semivolatile hydrocarbons and 99 percent of volatile aromatics and aliphatics were removed;
- Contaminant removal at the 2-meter depth, the fringe of the heated zone, exceeded 95 percent;
- The 70 to 76 percent contaminant reduction in the immediate area outside the heated zone indicates that there was no net migration of contaminant from the heated area to the surrounding soil; and

- Results show that substantial removal of high boiling contaminants can be achieved at temperatures significantly lower than their boiling point. This occurs due to the long residence time provided at lower temperatures and steam distillation provided by the native moisture.

### Remediation Costs

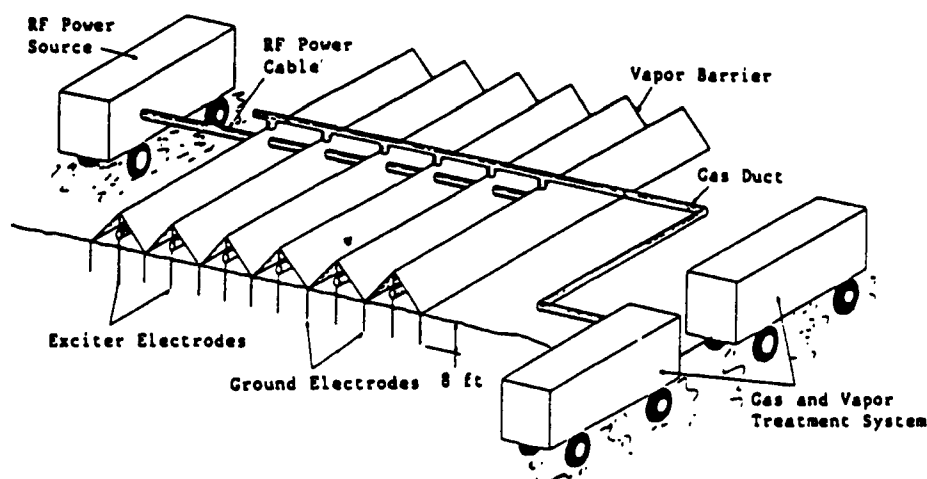
It is estimated that the treatment cost will vary between \$28 to \$60 per ton of soil. Based on bench-scale tests, it is estimated that the treatment of a 3-acre site to a depth of 8 feet containing 12 percent moisture raised to a temperature of 170°C would cost \$42 per ton. The treatment of such a site would require about one year. The initial capital equipment investment for full-scale projects is estimated to be about \$1.5 million. Power requirements are approximately 500 kilowatt-hours per cubic yard to reach a temperature of 150°C.

### General Site Information

A bench-scale pilot test (volume <20 drums) has been conducted at ITT Research Institute facilities. A full-scale demonstration was completed in seven feet of sandy soil at Volk Field (ANGB), Wisconsin, during October 1989. Another pilot-scale demonstration began during the Fall of 1991 at Kelly AFB, San Antonio, Texas, in clay soil from 10 to 30 feet deep.

### Contact

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RF Thermal Soil Decontamination Process



## **X\*TRAX™ Thermal Desorption**

### **Volatile and Semivolatile Organics and PCBs in Soil**

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#### **Technology Description**

The X\*TRAX™ technology is a thermal desorption process designed to remove organic contaminants from soils, sludges, and other solid media. It is not an incinerator or a pyrolysis system. Chemical oxidation and reactions are not encouraged, and no combustion by-products are formed. The organic contaminants are removed as a condensed liquid, characterized by a high Btu rating, which may then be either destroyed in a permitted incinerator or used as a supplemental fuel. Because of low operating temperatures (200°F to 900°F) and gas flow rates, this process is less expensive than incineration.

An externally fired rotary dryer is used to volatilize the water and organic contaminants into an inert carrier gas stream. The processed solids are then cooled with treated condensed water to eliminate dusting. The solids are ready to be placed and compacted in their original location.

The organic contaminants and water vapor driven from the solids are transported out of the dryer by an inert nitrogen carrier gas. The carrier gas flows through a duct to the gas treatment system, where organic vapors, water vapors, and dust particles are removed and recovered from the gas. The gas first passes through a high-energy scrubber. Dust particles and 10 to 30 percent of the organic contaminants are removed by the scrubber. The gas then passes through two heat condensers in series, where it is cooled to less than 40°F.

Most of the carrier gas passing through the gas treatment system is reheated and recycled to the dryer. Approximately 5 to 10 percent of the gas is cleaned by passing it through a particulate filter and a carbon adsorption system before it

is discharged to the atmosphere. The volume of gas released from this process vent is approximately 100 to 200 times less than an equivalent capacity incinerator. This discharge helps maintain a small negative pressure within the system and prevents potentially contaminated gases from leaking. The discharge also allows makeup nitrogen to be added to the system, preventing oxygen concentrations from exceeding combustibility limits.

The process can remove and collect volatiles, semivolatiles, and polychlorinated biphenyls (PCB), and has been demonstrated on a variety of soils ranging from sand to very cohesive clays. In most cases, volatile organics are reduced to below 1 ppm and frequently to below the laboratory detection level. Semivolatile organics are typically reduced to less than 10 ppm and frequently below 1 ppm. Soils containing 120 ppm to 6,000 ppm PCBs have been reduced to 2 ppm to 25 ppm. Removal efficiencies from 96 to 99+ percent have been demonstrated for soils contaminated with various organic pesticides.

Minimal feed pretreatment is required. The feed material must be screened to a particle size of less than 2 inches. For economic reasons, a single location should have a minimum of 5,000 cubic yards of material. For most materials, the system can process 120 to 150 tons per day at a cost of \$150 to \$250 per ton.

#### **Technology Performance**

Chemical Waste Management (CWM) currently has three X\*TRAX™ systems available: laboratory-, pilot-, and full-scale. Two laboratory-scale systems are being used for treatability studies. One system is operated by

Chem Nuclear systems, Inc., in Barnwell, South Carolina, for mixed (Resource Conservation and Recovery Act [RCRA]/Radioactive) wastes; the other is operated by CWM Research and Development at its facility in Geneva, Illinois, for RCRA and Toxic Substance Control Act (TSCA) wastes. More than 60 tests have been completed since January 1988. Both laboratory systems are available for performing treatability studies. A draft report is furnished within 12 weeks of sample receipt.

A pilot-scale system is in operation at the CWM Kettleman Hills facility in California. During 1989 and 1990, 10 different PCB-contaminated soils were processed under a TSCA Research and Development (R&D) permit, which expired in January 1990. The system is currently operating under both an EPA Research Development and Demonstration and a California Department of Health and Safety R&D permit for RCRA materials. Pilot testing is planned through November 1992.

The first Model 200 full-scale X\*TRAX™ system was completed in early 1990. The system is being used to remediate 35,000 tons of PCB-contaminated soil at the Resolve Superfund site in Massachusetts. EPA plans to conduct a SITE demonstration during this remediation.

#### **Remediation Costs**

No cost information is available.

#### **Contacts**

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## **Vapor Extraction**



## **Ground Water Vapor Recovery System**

### **Volatile Organic Compounds in Ground Water (In Situ Treatment)**

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#### **Technology Description**

In this treatment, injection and extraction wells are placed outside and inside of an area of contamination. Positive pressure, from either water or air, is placed on the injection wells. Water is pumped from the extraction wells to a thermal aeration system to drive off the contaminants. Resulting vapors go to an internal combustion engine. If enough free product is available in the ground water during the cleanup process, waste hydrocarbons could be used to power the engine without the need for additional fuel.

#### **Technology Performance**

Full-scale implementation of this system began in 1991 at the Seal Beach Navy Weapons Station. This method is applicable for volatile fuels or other volatile organic compounds. This treatment requires that the contaminant be combustible. Air permits are required in some areas.

#### **Remediation Costs**

The capitol cost for purchasing and installing the engine and wells is between \$70,000 and \$100,000.

#### **Contacts**

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## **In Situ Air Stripping with Horizontal Wells TCE and PCE in Soil and Ground Water**

### **Technology Description**

In situ air stripping using horizontal wells is designed to concurrently remediate unsaturated-zone soils and ground water containing volatile organic compounds (VOCs). The in situ air stripping concept utilizes two parallel horizontal wells: one below the water table and one in the unsaturated (vadose) zone. A diagram of the technology has been provided. The deeper well is used as a delivery system for the air injection. VOCs are stripped from the ground water into the injected vapor phase and are removed from the subsurface by drawing a vacuum on the shallower well in the vadose zone. The technology is based on Henry's Law, and the affinity of VOCs for the vapor phase. The technology is probably most effective in soils with high permeability and likely works best in sandier units with no significant aquitards between the injection and extraction wells. Horizontal wells are used because they provide more surface area for injection of reactants and extraction of contaminants and they have great utility for subsurface access under existing facilities.

First, a vacuum was drawn on the shallow well for a period of two weeks. Concentration and temperature of the extracted vapors were measured at least three times a day. Air injection was then added at three different rates and at two different temperatures. Each of the operating regimes was operated for a minimum of two weeks. Helium tracer tests were also conducted to learn more about vapor flow paths and the heterogeneity of the system between the two wells. To assist with analysis and monitoring of the demonstration, tubes of varying lengths were installed in both horizontal

wells to monitor pressure and concentrations along their entire length.

### **Technology Performance**

Almost 16,000 pounds of solvents were removed during the test at the U.S. Department of Energy's (DOE) Savannah River Site (SRS). Extraction rates during the vapor extraction phase averaged 110 pounds of VOCs per day. The extraction flow rate was constant at approximately 580 scfm during the entire length of the test. During the air injection periods with medium (170 scfm) and high (270 scfm) rates, approximately 130 pounds of VOCs were removed daily.

Concentrations of chlorinated solvents removed during vapor extraction only decreased rapidly during the first two days of operation. Initial concentrations were as high as 5,000 ppm but stabilized at 200-300 ppm. Concentrations of VOCs in the ground water were significantly reduced in several of the monitoring wells. For example, ground water from two monitoring wells showed changes from 1600 and 1800 µg/L TCE at the beginning of the test to 10-30 µg/L at the end of the 20-weeks. However, ground water in several of the wells showed no significant change and ground water in three wells actually had trichlorethylene (TCE) concentrations increase. One possible explanation for this was that more contaminated water at depth (below the monitoring point) was being forced upward due to air injection.

The activity of indigenous microorganisms was found to increase at least an order of magnitude during the air injection periods. This activity then decreased when the air injection was terminated. It is possible that simple injection

of air stimulated microorganisms that have the potential to degrade TCE. Injection of heated air appeared to have no effect on the amount of contaminant extracted from the shallow well.

### **Remediation Costs**

The cost of the remediation project, not including site characterization was approximately \$300,000, or \$20 per pound of contaminant removed. Site preparation costs, including well installation were \$300,000 to \$450,000. Equipment for this demonstration test was rented; however, purchase of the vacuum blower and compressor would be in the range of \$200,000.

### **General Site Information**

This 20-week field demonstration project was conducted at the U.S. Department of Energy's (DOE) Savannah River Site (SRS) in Aiken, South Carolina, between July and December, 1990. Trichloroethylene (TCE) and tetrachloroethylene (PCE) were used at SRS as metal degreasing solvents for a number of years. The in situ test was conducted at the SRS Integrated Demonstration Site in the M-Area, along an abandoned process sewer line that carried wastes to a seepage basin which was operated between 1958 and 1985. A ground water plume containing elevated levels of these compounds exists over an area greater than one square mile. The sewer line acted as a source of VOCs as it is known to have leaked at numerous locations along its length. Because the source of contamination was linear at this particular location within the overall plume, horizontal wells were selected as the injection/extraction system.

The Savannah River Site is located on the upper Atlantic Coastal Plain. The site is underlain by a thick wedge of unconsolidated Tertiary and Cretaceous sediments that overlay the basement, which consists of preCambrian and Paleozoic metamorphic rocks and consolidated Triassic sediments. Ground-water flow at the site is controlled by hydrologic boundaries: flow at and immediately below the water table is to local tributaries; and flow in the lower aquifer is to the Savannah River or one of its major tributaries. The water table is located at approximately 135 feet. Ground water in the vicinity of the process sewer line contains elevated concentrations of TCE and PCE to depths of greater than 180 feet.

### **Contacts**

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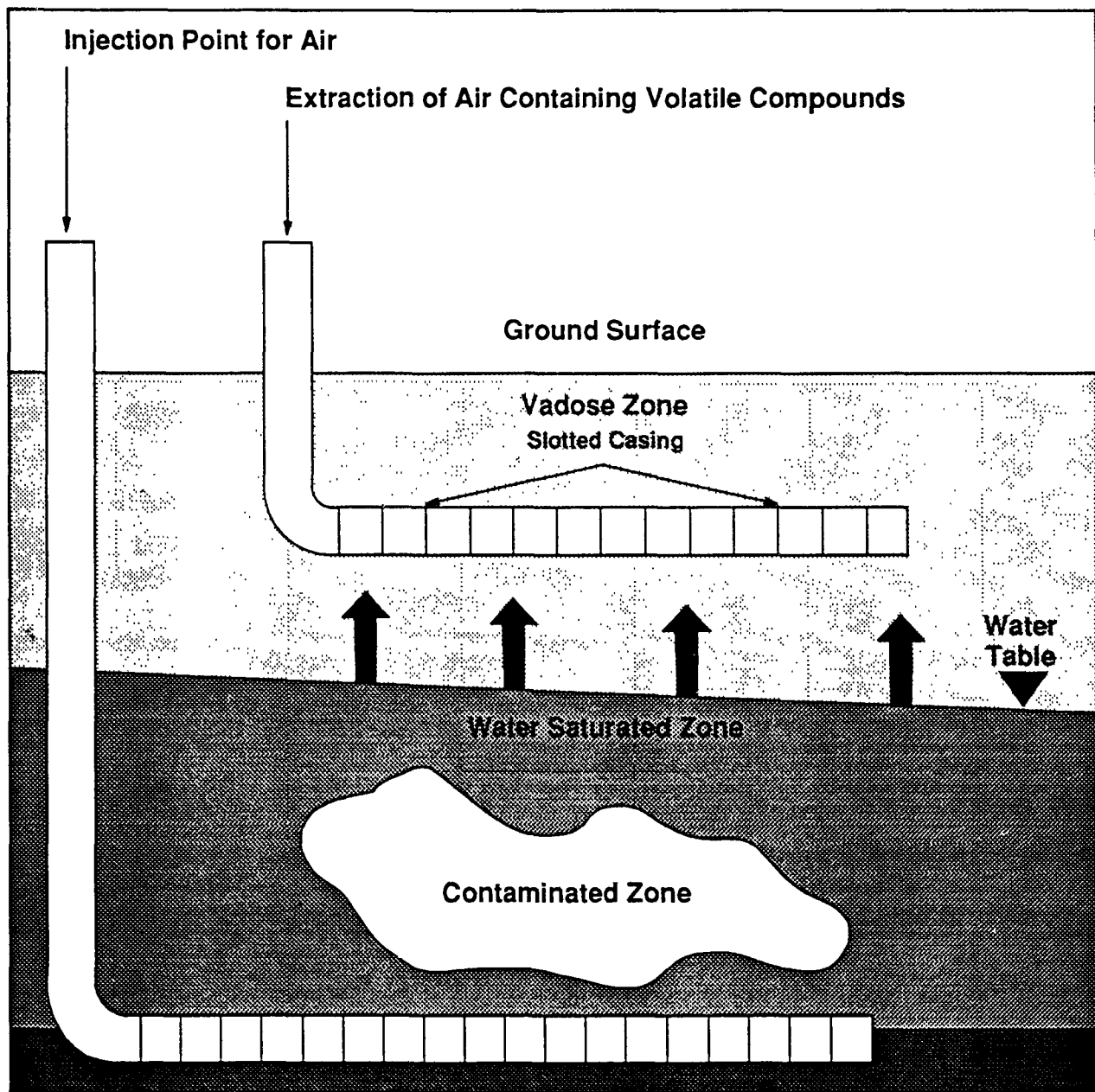


Diagram of In Situ Air Stripping with Horizontal Wells



## **In Situ Soil Vapor Extraction**

### **Industrial Sludge, Waste Solvents, Fuel and Oil in Soils**

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#### **Technology Description**

This technology is used to treat soils contaminated with volatile organic compounds (VOCs) including TCE, DCE, vinyl chloride, toluene, chlorobenzenes, and xylenes. The process is used in vadose zone soils. The technology does not work in ground water or saturated zone soils and is ineffective for removal of semivolatiles and metals.

Vadose zone extraction wells are installed at various targeted depths. A vacuum is applied and contaminants are pulled to the surface where they are treated with a catalytic oxidation unit prior to discharge to the atmosphere.

#### **Technology Performance**

A large scale pilot test involving 17 wells is scheduled to begin in Fall 1992 at McClellan Air Force Base in California. Target contaminants are VOCs in the 100-1,000 ppm range. In addition, the Air Force will evaluate the effectiveness of enhancements such as hot air injection into the waste pit materials. The test is scheduled to be completed in Spring 1993.

#### **Remediation Costs**

No cost information is available.

#### **General Site Information**

The test is being conducted at a former fuel and solvent disposal site in the northwest part of McClellan Air Force Base in California, a Superfund site. The test area is one of 15 such sites located in Operable Unit D and contains

approximately 400,000 cubic feet of contaminated soil.

#### **Contacts**

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## **In Situ Soil Venting**

### **Fuels and Trichloroethylene in Unsaturated Soils**

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#### **Technology Description**

The in situ soil venting process removes volatile contaminants such as fuels and trichloroethylene from unsaturated soils. This technology can be applied to fire training pits, spills and the unsaturated zone beneath leach pits. The method is most applicable for contamination in fairly permeable soils.

Venting wells are placed in the unsaturated zone and connected to a manifold and blower. A vacuum is applied to the manifold, and gases are extracted from the soil and fed to the treatment system. The air flow sweeps out the soil gas, disrupting the equilibrium existing between the contaminant adsorbed on the soil and its vapor phase. This results in further volatilization of the contaminant on the soil and subsequent removal in the air stream. Depending upon the individual site and the depth of the contaminated zone, it might be necessary to seal the surface to the throughput of air.

This technology has a number of advantages. Specifically, it is inexpensive, especially if the emissions require no treatment. The equipment is easily emplaced. It is less expensive than excavation at depths greater than 40 feet. Operation is simple, excavation of contaminated soil is not required, and the site is not destroyed.

Despite the advantages of this technology, limitations do exist. This process is a transfer-of-media method; the waste is not destroyed. At depths of less than 10 feet, excavation could be less expensive, depending upon the type of waste treatment required. The contamination must be located in the unsaturated zone above the nearest aquifer. Prior bench-scale testing is important in determining the effectiveness of the

method to a specific site. To date, few field data exist on the level of cleanup. If the contamination includes toxic volatile organic carbons, then treatment of the vented gases may be required. The level of treatment is based upon local requirements.

#### **Technology Performance**

Analysis of the technology demonstration at Hill Air Force Base (AFB) in Utah have shown the following results:

- Soil gas venting may provide oxygen for biodegradation;
- Based on data from extracted gases, 80 percent of a 100,000-liter fuel spill was removed in 9 months of operation;
- Soil analysis following a full-scale in situ field test indicated an average fuel residual of less than 100 ppm in the soils;
- At initial air flow rates of 250 cubic feet per minute, the full-scale system was removing 50 gallons per day of JP-4 from the soil. The venting rates were then increased to over 1,000 cubic feet per minute. After 10 months of venting, over 100,000 pounds of JP-4 had been removed. Hill AFB continues to operate the system at a reduced flow rate to enhance the in situ biodegradation of remaining hydrocarbons; and
- Approximately 20-25 percent of the reduction in fuel hydrocarbons was caused by biodegradation.

## **Remediation Costs**

The costs range from \$15 per ton of contaminated soil, excluding emission treatment, up to approximately \$85 per ton using activated carbon emission treatment. Estimated costs of this technology for sandy soils is \$10 per cubic yard. Catalytic incineration of VOCs can double this cost. However, at Hill AFB, catalytic incineration only cost \$10 per cubic yard.

## **General Site Information**

Operation of a full-scale in situ soil-venting system at a 27,000-gallon JP-4 spill at Hill AFB, Utah, began in December 1988. A full-scale in situ field test was completed in October

1989 at Hill AFB. ESL TR 90-21 Vol I, *Literature Review*, Vol II, *Soil Venting Guidance Manual*, and Vol III, *Full Scale Test Results*, available from the National Technical Information Service (NTIS), are a result of this effort. A cost spreadsheet is part of the design manual (Vol II) for soil venting systems and is available on request from the contact below.

## **Contact**

Hill Air Force Base Demonstration:  
Capt. Edward G. Marchand  
HQ AFCESA/RAVW  
Tyndall AFB, Florida 32403-5001  
904/283-6023



## **In Situ Soil Venting Volatile Contaminants in Unsaturated Soil**

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### **Technology Description**

This in situ soil venting process removes volatile contaminants from unsaturated soils. This technology can be applied to fire training pits, spills, and the unsaturated zone beneath leach pits. The method is most applicable for contamination at depths greater than 40 feet in fairly permeable soils.

Venting wells are placed in the unsaturated zone and connected to a manifold and blower. A vacuum is applied to the manifold, and gases are extracted from the soil and fed to the treatment system. Depending upon the individual site and depth of the contaminated zone, it might be necessary to seal the surface to prevent channeling. Air injection wells can be used to increase the throughput of air.

### **Technology Performance**

Pilot-scale testing at the Twin Cities Army Ammunition Plant (TCAAP) has removed 70 tons of contaminants from the soil in one area, but the absolute extent of cleanup has not yet been determined. This method is considered most applicable for contamination at depths greater than 40 feet in fairly permeable soils.

### **Remediation Costs**

The costs for in situ soil venting can be as low as \$15 per ton of contaminated soil, excluding emission treatment. If carbon adsorption treatment is used, the costs could be around \$85 per ton. Based upon the pilot study at TCAAP, the cost to treat a site contaminated to a depth of 20 feet was between \$15 and \$20 per cubic yard, including carbon adsorption treatment of the contaminated air and soil sampling.

### **General Site Information**

This method has been implemented by the Army at the Twin Cities Army Ammunition Plant (TCAAP) in Minnesota.

### **Contacts**

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## **In Situ Steam and Air Stripping**

### **Volatile and Semivolatile Organics and Hydrocarbons in Soil**

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#### **Technology Description**

In this technology, a transportable treatment unit "Detoxifier" is used for in situ steam and air stripping of volatile organics from contaminated soil.

The two main components of the on-site treatment equipment are the process tower and process train. The process tower contains two counter-rotating hollow-stem drills, each with a modified cutting bit 5 feet in diameter, capable of operating to a 27-foot depth. Each drill contains two concentric pipes. The inner pipe is used to convey steam to the rotating cutting blades. The steam is supplied by an oil-fired boiler at 450°F and 450 psig. The outer pipe conveys air at approximately 300°F and 250 psig to the rotating blades. Steam is piped to the top of the drills and injected through the cutting blades. The steam heats the ground being remediated, increasing the vapor pressure of the volatile contaminants, and thereby increasing the rate at which they can be stripped. Both the air and steam serve as carriers to convey these contaminants to the surface. A metal box, called a shroud, seals the process area above the rotating cutter blades from the outside environment, collects the volatile contaminants, and ducts them to the process train.

In the process train, the volatile contaminants and the water vapor are removed from the off-gas stream by condensation. The condensed water is separated from the contaminants by distillation, then filtered through activated carbon beds and subsequently used as make-up water for a wet cooling tower. Steam is also used (1) to regenerate the activated carbon beds and (2) as the heat source for distilling the volatile contaminants from the condensed liquid stream. The recovered concentrated organic

liquid can be recycled or used as a fuel in an incinerator.

This technology is applicable to volatile organic compounds (VOC), such as hydrocarbons and solvents, with sufficient vapor pressure in the soil. The technology is not limited by soil particle size, initial porosity, chemical concentration, or viscosity. The process is also capable of significantly reducing the concentration of semivolatile organic compounds in soil.

#### **Technology Performance**

A SITE demonstration was performed during the week of September 18, 1989, at the Annex Terminal, San Pedro, California. Twelve soil blocks were treated for VOCs and semivolatile organic compounds (SVOC). Various liquid samples were collected from the process during operation, and the process operating procedures were closely monitored and recorded. Post-treatment soil samples were collected and analyzed by EPA methods 8240 and 8270. In January 1990, six blocks that had been previously treated in the saturated zone were analyzed by EPA methods 8240 and 8270. The Applications Analysis Report (EPA/540/A5-90/008) was published in June 1991.

The following results were obtained during the SITE demonstration of the technology:

- More than 85 percent of the VOCs in the soil was removed.
- Up to 55 percent of SVOCs in the soil was removed.
- Fugitive air emissions from the process were very low.
- No downward migration of contaminants resulted from the soil treatment.



- The process was timely with a treatment rate of 3 cubic yards per hour.

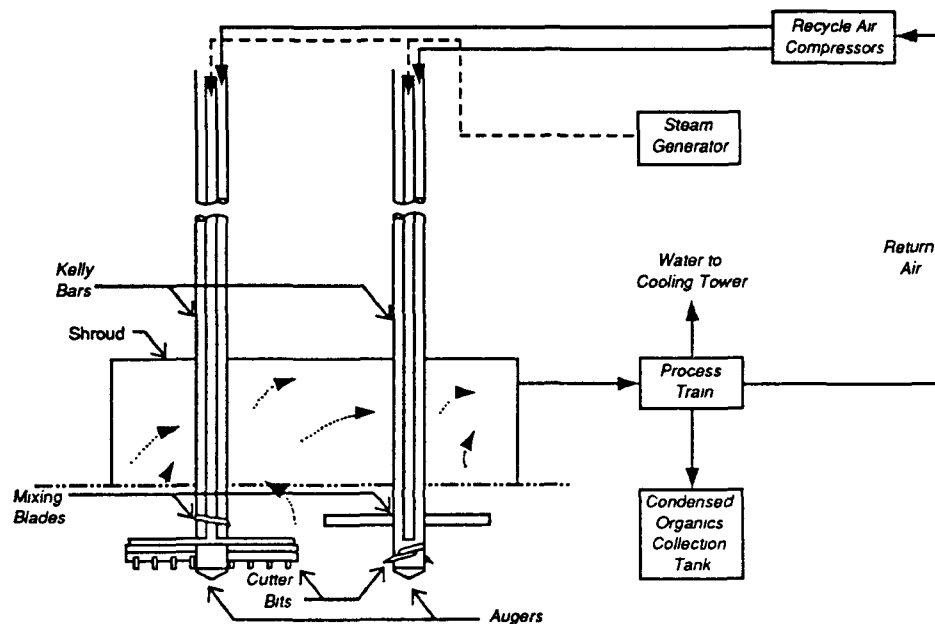
### Remediation Costs

No cost information is available.

### Contacts

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Process schematic



## **In Situ Steam-Enhanced Extraction (ISEE) Volatile and Semivolatile Organics in Soil**

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### **Technology Description**

The in situ steam-enhanced extraction (ISEE) process, developed by Udel Technologies Inc., removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils both above and below the water table. Steam is forced through the soil by injection wells to thermally enhance the vapor and liquid extraction processes. The extraction wells have two purposes: to pump and treat ground water and to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are either condensed and processed with the contaminated ground water or trapped by gas-phase activated carbon filters. The technology uses readily available components, such as injection and extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

The process is used to extract VOCs and SVOCs from contaminated soils and ground water. The primary applicable compounds are hydrocarbons such as gasoline, diesel, and jet fuel, solvents such as trichloroethylene (TCE), trichloroethane (TCA), and dichlorobenzene (DCB), or a mixture of these compounds. The process may be applied to contaminants below the water table. After application of this process, the subsurface conditions are excellent for biodegradation of residual contaminants, if necessary. The process cannot be applied to contaminated soil very near the surface unless a cap exists.

Denser-than-water compounds may be treated only in low concentrations unless a geologic barrier exists to prevent downward percolation of a separate phase.

### **Technology Performance**

In August 1988, a successful pilot-scale demonstration of the process was completed at a site contaminated by a mixture of solvents; 764 pounds of contaminants were removed from the 10-foot-diameter, 12-foot-deep test region.

The technology is scheduled to be demonstrated under the SITE Demonstration Program at a burn pit with soil contaminated by waste oil mixed with VOCs, SVOCs, and metals at McClellan Air Force Base in Sacramento, California. The treatability studies on the McClellan contaminated wastes and soils were performed in fall 1991.

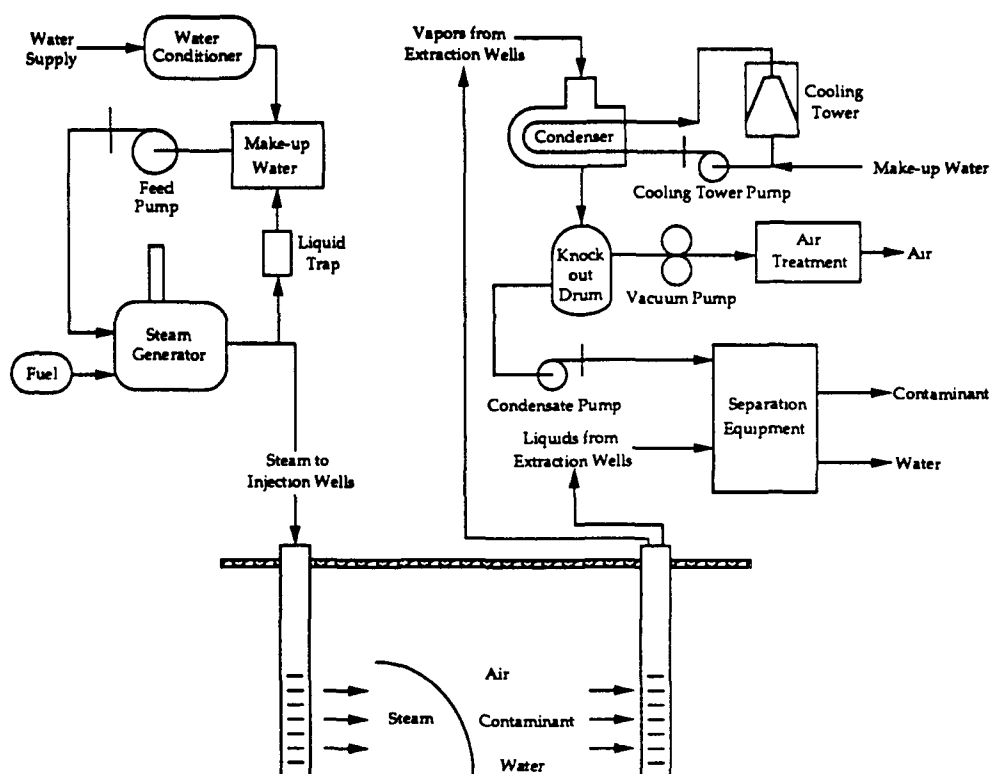
Also, a case study will be performed to remediate a gasoline spill both above and below the water table to depths of 137 feet at the Lawrence Livermore National Laboratory in Livermore, California.

An interagency agreement between the Naval Civil Engineering Laboratory (NCEL) in Port Hueneme, California and the Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio has been reached. NCEL and RREL are considering a demonstration of this process at the LeMoore Naval Air Station.

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In situ Steam Enhanced Extraction process schematic



## **Integrated Vapor Extraction and Steam Vacuum Stripping VOCs in Soil and Ground Water (In Situ Treatment)**

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### **Technology Description**

The integrated AquaDetox/SVE system simultaneously treats ground water and soil contaminated with volatile organic compounds (VOCs). The integrated system consists of two basic processes: an AquaDetox moderate vacuum stripping tower that uses low-pressure steam to treat contaminated ground water; and a soil gas vapor extraction/reinjection (SVE) process to treat contaminated soil. The two processes form a closed-loop system that provides simultaneous in situ remediation of contaminated ground water and soil with no air emissions.

AquaDetox is a high-efficiency, counter-current stripping technology developed by Dow Chemical Company. A single-stage unit will typically reduce up to 99.99 percent of VOCs from water. The SVE system uses a vacuum to treat a VOC-contaminated soil mass, inducing a flow of air through the soil and removing vapor phase VOCs with the extracted soil gas. The soil gas is then treated by carbon beds to remove additional VOCs and reinjected into the ground. The AquaDetox and SVE systems share a granulated activated carbon (GAC) unit. Noncondensable vapor from the AquaDetox system is combined with the vapor from the SVE compressor and is decontaminated by the GAC unit. By-products of the system are a free-phase recyclable product and treated water. Mineral regenerable carbon will require disposal after approximately three years.

A key component of the closed-loop system is a vent header unit designed to collect the noncondensable gases extracted from the ground water or air that may leak into the portion of the process operating below atmospheric pressure. Further, the steam used to regenerate the carbon

beds is condensed and treated in the AquaDetox system. This technology removes VOCs, including chlorinated hydrocarbons, in ground water and soil. Sites with contaminated ground water and soils containing trichloroethylene (TCE), perchloroethylene (PCE), and other VOCs are suitable for this on-site treatment process. AquaDetox is capable of effectively removing over 90 of the 110 volatile compounds listed in 40 CFR Part 261, Appendix VIII.

### **Technology Performance**

The AWD AquaDetox/SVE system is currently being used at the Lockheed Aeronautical Systems Company in Burbank, California. At this site, the system is treating ground water contaminated with as much as 2,200 ppb of TCE and 11,000 ppb PCE; and soil gas with a total VOC concentration of 6,000 ppm. Contaminated ground water is being treated at a rate of up to 1,200 gpm while soil gas is removed and treated at a rate of 300 cubic feet per minute (cfm). The system occupies approximately 4,000 square feet. A SITE demonstration project was evaluated as part of the ongoing remediation effort at the San Fernando Valley Groundwater Basin Superfund site in Burbank, California. Demonstration testing was conducted in September 1990. The Applications Analysis Report (EPA/540/A5-91/002) was published in October 1991.

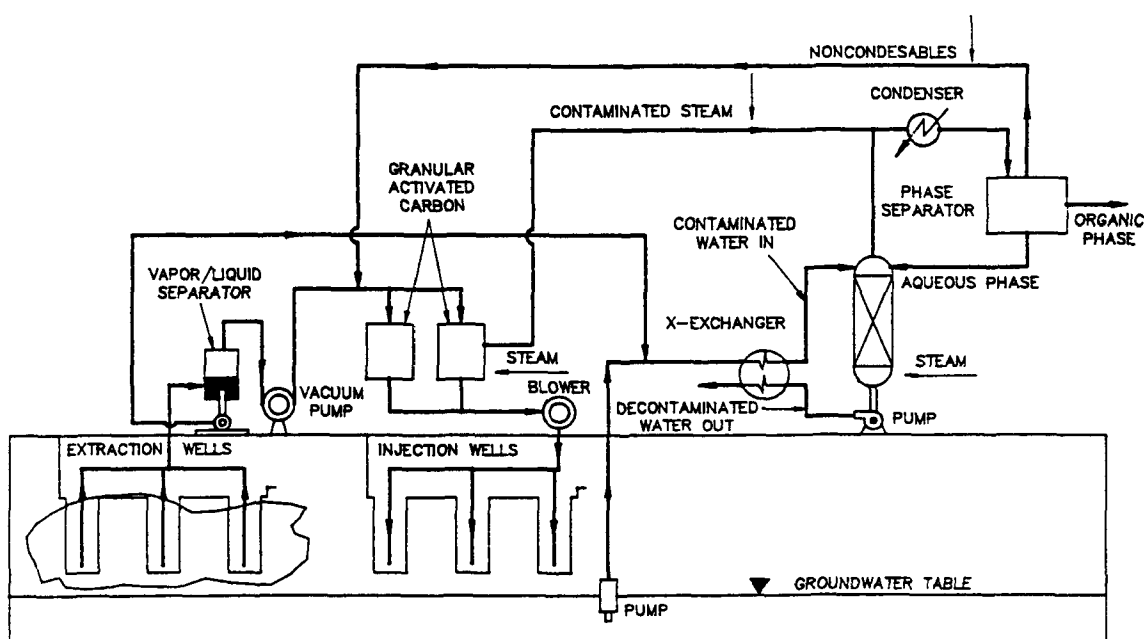
### **Remediation Costs**

No cost information is available.

## Contacts

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Zero air emissions integrated AquaDetox/SVE system



## Soil Vapor Extraction (SVE) JP-4 Jet Fuel (In Situ Treatment)

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### Technology Description

This technology consists of a system of air extraction wells installed throughout the contaminated soils. The wells are connected to a blower system capable of extracting air through the soil matrix. Volatile compounds present in the soil gas and adsorbed on the soils are volatilized and withdrawn from the soil. Soil vapor extraction also can be used to enhance biological processes in the soil to treat semivolatiles or non-volatiles by increasing the oxygen content of the soil gas.

The SVE system may consist of one or more 4-inch PVC inlet and/or air extraction wells. The anticipated depth of the wells will be about 60 feet. The system can be skid-mounted and located away from the impacted area. It includes a blower with muffler, air/water separator, vacuum relief valve, and gauges. Sample ports and direct reading instrumentation also can be included. Air emissions can be treated by a thermal treatment unit or granular activated carbon (GAC). Volatile compounds in the blower discharge will be treated before discharging to the atmosphere. If GAC is selected, the spent carbon and liquid wastes resulting from condensation of soil moisture in the SVE system are then disposed of at a permitted treatment facility.

### Technology Performance

Full-scale remediation of the North Fire Training Area at Luke Air Force Base in Glendale, Arizona, is scheduled to be completed by the end of 1992. The SVE system to be used consists of two 60-foot extraction wells operating at 100 scfm. Target contaminants are benzene at 16 ppm, ethylbenzene at 84 ppm, toluene at 183 ppm, xylene at 336 ppm, and TRPH at 1,380 ppm. Soil borings and soil gas

samples will be used to evaluate effectiveness of the treatment. Residual condensate will be collected from extraction well piping at a rate of eight gallons per day and incinerated.

### Remediation Costs

No cost information is available.

### General Site Information

The remediation involves 35,000 cubic yards of contaminated soil at the North Fire Training Area at Luke Air Force Base in Glendale, Arizona. Currently not in use, the area had been the scene of fire training exercises using JP-4 jet fuel since 1973.

### Contacts

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## **Steam Injection and Vacuum Extraction (SIVE) Volatile and Semivolatile Organics in Soil and Ground Water (In Situ Treatment)**

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### **Technology Description**

The steam injection and vacuum extraction (SIVE) process, developed by Hughes Environmental Systems, removes most volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils in situ, both above and below the water table. The technology is applicable to in situ remediation of contaminated soils well below ground surface, and can be used to treat below or around permanent structures, accelerates contaminant removal rates, and can be effective in all soil types. Steam is forced through the soil by injection wells to thermally enhance the vacuum process. The extraction wells have two purposes: to pump and treat ground water, and to transport steam and vaporized contaminants under vacuum to the extraction well and then to the surface. Recovered contaminants are either condensed and processed with the contaminated ground water or trapped by gas-phase activated carbon filters. The technology uses readily available components, such as extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

The process is used to extract volatile and semivolatile organic compounds from contaminated soils and perched ground water. The primary applicable compounds are hydrocarbons such as gasoline, diesel and jet fuel; solvents such as trichloroethylene (TCE), trichloroethane (TCA), and dichlorobenzene (DCB); or a mixture of these compounds. After application of this process, the subsurface conditions are excellent for biodegradation of residual contaminants. The process cannot be applied to contaminated soil very near the surface unless a cap exists. Denser-than-water compounds may be treated only in low

concentrations unless a geologic barrier exists to prevent downward percolation of a separate phase.

### **Technology Performance**

The SITE demonstration for this technology has been conducted at a site in Huntington Beach, California. The soil at the site was contaminated by a 135,000 gallon diesel fuel spill.

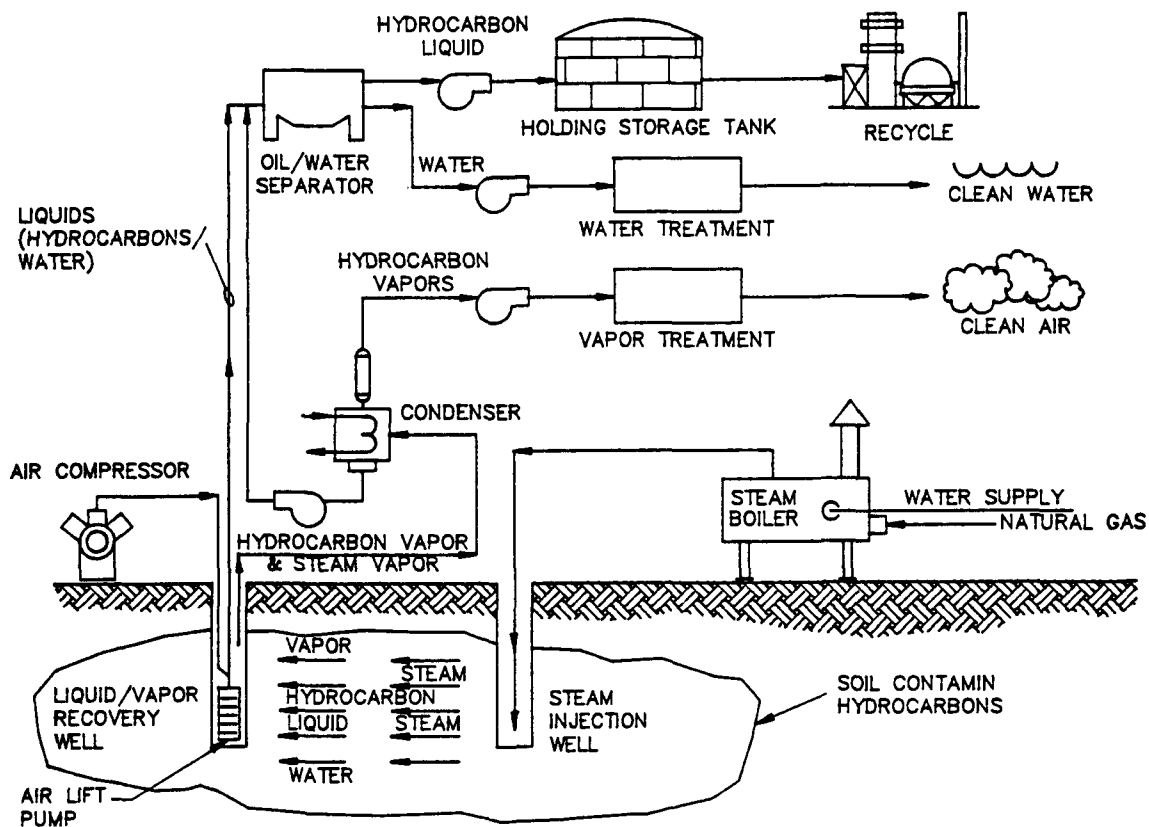
### **Remediation Costs**

No cost information is available.

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Steam Injection and Vapor Extraction process





## **Vacuum-Induced Soil Venting Gasoline in Unsaturated Soil (In Situ Treatment)**

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### **Technology Description**

The vacuum-induced venting process provides in situ cleanup of gasoline contamination above and below the water table. It reduces contamination to levels low enough to eliminate further leaching or desorption of gasoline into the ground water. This technology can be applied to hydrocarbon fuels in unsaturated soil.

A vapor/ground-water extraction well, and a well for monitoring the vacuum induced venting were installed in the gas spill area. The vapor extraction/monitor wells each have five individually screened intervals in the unsaturated zone and two screened intervals below the water table. A vacuum-extraction system with thermal oxidizer is installed using one well to remediate the spill area. The vacuum-extraction system operates with a vacuum of between 20-25 inches of mercury and with a flow rate of approximately 60 cfm. The present system uses an open pipe at the top of an air-driven pump, which is manually adjusted to follow the gasoline water interface. Both wells are used for skimming gasoline.

### **Technology Performance**

Results from testing the vacuum-induced soil venting technology at the Department of Energy's (DOE) Lawrence Livermore National Laboratory (LLNL) were positive:

- Approximately 100 gallons of free product were removed with this system;
- Approximately 5,000 gallons of gasoline were removed via vacuum-induced venting over a 12-month period;

- Over the 12-month period, total fuel hydrocarbon concentrations (measured at the inlet of the thermal oxidizer), decreased from 16,000 ppm to about 3,000-4,000 ppm; and
- The thermal oxidizer that destroys the gaseous hydrocarbons as they are removed operated with a 99.8 percent destruction efficiency.

### **Remediation Costs**

Cost information is not available.

### **General Site Information**

Prior to 1979, approximately 17,000 gallons of regular gasoline leaked into the soil and ground water from an underground fuel storage tank at the DOE's Lawrence Livermore National Laboratory. Vacuum-induced venting was demonstrated at this site as a method to clean the gasoline contamination in situ.

### **Contacts**

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### Vapor Extraction and Bioventing Design Gasoline in Soil and Ground Water (In Situ Treatment)

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#### Technology Description

To date, the practice of vapor extraction has not included the application of air flow and vapor transport models to guide data collection techniques for site characterization and to define optimal extraction and injection well locations. Quantification of the flow patterns associated with a vapor extraction design will lead to rational estimates of clean-up criteria and system performance.

The U.S. Geological Survey (USGS) ground water flow simulator MODFLOW has been adapted to perform airflow simulations. This airflow simulator, referred to as AIRFLOW, has been coupled with an optimization algorithm to formally predict the location and pumping rates for wells for the best venting system design given the site geology. A vapor transport code is under development that will allow for the calculation of enhanced microbial degradation (bioventing) associated with the vapor extraction system.

#### Technology Performance

The success of model application fundamentally depends on the ability to characterize the air permeability in the unsaturated zone. Heterogeneity with respect to air permeability due to stratification of sediments and variable moisture content distribution must be considered for site specific application of the models. At the USGS gasoline spill research site at Galloway Township, New Jersey, field methods have been developed to determine the distribution of air permeability in the unsaturated zone. AIRFLOW has been successfully applied to quantify the flow paths for a venting design. A vapor concentration

data base is being constructed for future application of the vapor transport code for bioventing application.

#### General Site Information

Field research at the Galloway Township gasoline site began in 1988. The site is one of sandy sediments in the New Jersey Coastal Plain. Gasoline leaked from a small underground storage tank and contaminated shallow ground water. In addition to the venting and bioventing remediation study, an extensive investigation of natural attenuation mechanisms, including vapor transport and the natural rate of aerobic and anaerobic microbial degradation of hydrocarbons, is being conducted. The research team seeks to combine laboratory, field, and modeling techniques to develop practical methods for estimating the rates of contaminant movement and attenuation.

#### Contact

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## Vapor Extraction System Solvents in Soil (In Situ Treatment)

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### Technology Description

This technology uses a vacuum pump/blower to treat vadose zone soils contaminated with VOCs. The increased airflow in the vadose zone resulting from use of the vapor extraction system also assists in the biodegradation of other organics.

Vapor extracted using the process is treated using a thermal burner or catalytic oxidation prior to being discharged to the atmosphere. Entrained contaminated water, if any, is transported off site to a permitted facility for treatment.

### Technology Performance

Full-scale remediation of a site at the Sacramento Army Depot in California is scheduled to begin late in 1992. The process is expected to last six months. Target contaminants are ethylbenzene, butanone, xylene and PCE.

### Remediation Costs

No cost information is available.

### General Site Information

The remediation involves about 200 cubic yards of soil in the Tank 2 area of the Sacramento Army Depot in California. The tank has been removed. Contamination in the area was found to a depth of 18 feet, with the majority between 9 and 18 feet. The contaminated area currently is covered with a slab.

### Contacts

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## **Soil Washing**



## **BioGenesis<sup>®</sup> Soil Cleaning Process**

### **Volatile and Non-Volatile Hydrocarbons and PCBs in Soil**

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#### **Technology Description**

The BioGenesis<sup>®</sup> process uses a specialized truck, water, and a complex surfactant to clean contaminated soil. Ancillary equipment includes gravity oil and water separators, coalescing filters, and a bioreactor. The cleaning rate for oil contamination of 5,000 ppm is about 25 tons/hour; lesser rates apply for more contaminated soil. One single wash removes 95 to 99 percent of hydrocarbon contamination of up to 15,000 ppm. One or two additional washes are used for concentrations of up to 50,000 ppm.

BioGenesis<sup>®</sup> washing uses a complex surfactant and water. The BioVersal<sup>®</sup> cleaner is a light alkaline mixture of natural and organic materials containing no hazardous or petrochemical ingredients. Twenty-five tons of contaminated earth are loaded into a washer unit containing water and BioVersal<sup>®</sup> cleaner.

For 15 to 30 minutes, aeration equipment agitates the mixture, thus washing the soil, and encapsulating oil molecules with BioVersal<sup>®</sup> cleaner. After washing, the extracted oil is reclaimed, wash water is recycled or treated, and the soil is dumped from the soil washer. Hazardous organics, such as polychlorinated biphenyls (PCB), are extracted in the same manner and then processed by using treatment methods specific to that hazard. All equipment is mobile, and treatment is normally on site.

The advantages of BioGenesis<sup>®</sup> include (1) treatment of soils containing both volatile and non-volatile oils, (2) treatment of soil containing clay, (3) high processing rates, (4) on-site treatment, (5) transformation of contamination to reusable oil, treatable water, and active soil suitable for on-site treatment, (6) backfill, (7) the absence of air pollution, except during excavation, (8) and accelerated biodegradation of oil residuals in the soil.

This technology is capable of extracting volatile and nonvolatile oils, chlorinated hydrocarbons, pesticides, and other organics from most types of soils, including clays. These contaminants include asphalteens, heating oils, diesel fuel, gasoline, PCBs, and polycyclic aromatic hydrocarbons.

#### **Technology Performance**

BioGenesis<sup>®</sup> technology was commercialized in Germany during 1990. It was accepted into the SITE Demonstration Program in June 1990. Beale Air Force Base in California was the location for the SITE demonstration. Full commercial operations are scheduled for Wisconsin and California in 1992, with subsequent expansion to other regions.

Applied research continues to extend application of the technology to acid extractables, base and neutral extractables, pesticides, and acutely hazardous materials.

#### **Remediation Costs**

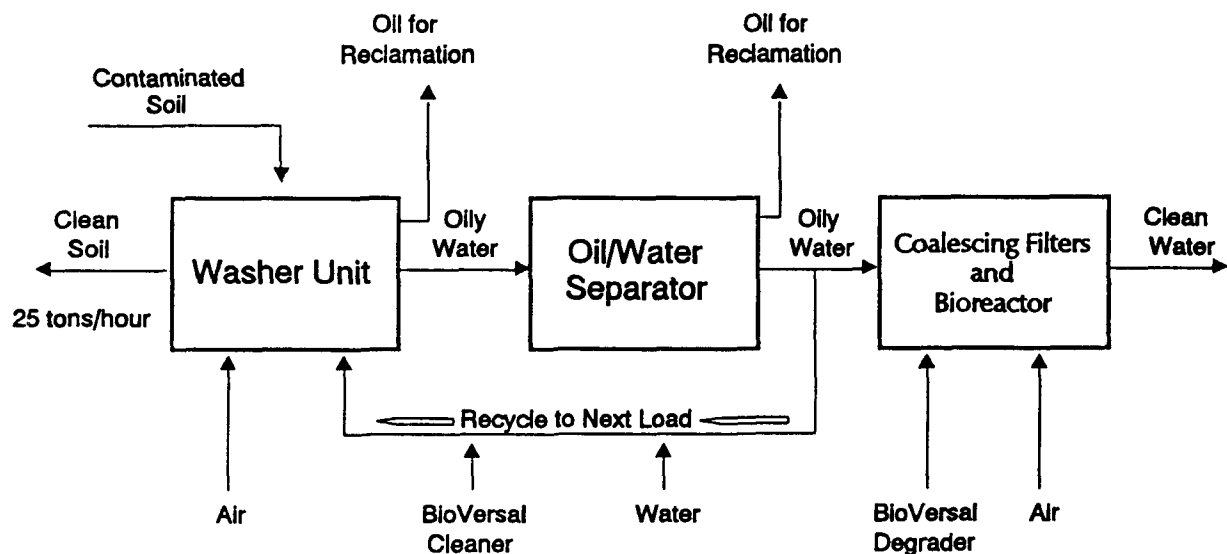
No cost information is available.

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Soil washing procedure



## **Contained Recovery of Oily Wastes (CROW) Process**

### **Coal Tar Derivatives and Petroleum Byproducts in Soil (In Situ Treatment)**

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#### **Technology Description**

The contained recovery of oily wastes (CROW) process recovers oily wastes from the ground by adapting a technology presently used for secondary petroleum recovery and for primary production of heavy oil and tar sand bitumen. Steam and hot-water displacement are used to move accumulated oily wastes and water to production wells for above ground treatment.

Injection and production wells are first installed in soil contaminated with oily wastes. Low-quality steam is then injected below the deepest penetration of organic liquids. The steam condenses, causing rising hot water to dislodge and sweep buoyant organic liquids upward into the more permeable soil regions. Hot water is injected above the impermeable soil regions to heat and mobilize the oil waste accumulations, which are recovered by hot-water displacement.

When the oily wastes are displaced, the organic liquid saturations in the subsurface pore space increase, forming an oil bank. The hot water injection displaces the oil bank to the production well. Behind the oil bank, the oil saturation is reduced to an immobile residual saturation in the subsurface pore space. The oil and water produced are treated for reuse or discharge.

In situ biological treatment may follow the displacement and is continued until ground-water contaminants are no longer detected in any water samples from the site. During treatment, all mobilized organic liquids and water-soluble contaminants are contained within the original boundaries of oily waste accumulations. Hazardous materials are contained laterally by ground-water isolation, and vertically by organic liquid flotation.

Excess water is treated in compliance with discharge regulations.

The process (1) removes large portions of oily waste accumulations, (2) stops the downward migration of organic contaminants, (3) immobilizes any residual saturation of oily wastes, and (4) reduces the volume, mobility, and toxicity of oily wastes. It can be used for shallow and deep contaminated areas, and uses the same mobile equipment required by conventional petroleum production technology.

This technology can be applied to manufactured gas plant sites, wood-treating sites, and other sites with soils containing organic liquids, such as coal tars, pentachlorophenol solutions, creosote, and petroleum by-products.

#### **Technology Performance**

Based on results of this project in the Emerging Technology Program, this technology was invited to participate in the SITE Demonstration Program.

This technology was tested both at the laboratory and pilot-scale under the SITE Emerging Technology Program. The program showed the effectiveness of the hot-water displacement and displayed the benefits from the inclusion of chemicals with the hot water.

The technology will be demonstrated at the Pennsylvania Power and Light (PP&L) Brodhead Creek site at Stroudsburg, Pennsylvania. The site contains an area of high concentrations of by-products from a former operation. The project is now in the planning and negotiation stage. Remediation Technologies, Inc., is participating in the

project. Other sponsors , in addition to EPA and PP&L, are the Gas Research Institute, the Electric Power Research Institute, and the U.S. Department of Energy.

In addition to the SITE Program, this technology is now being demonstrated at a wood-treatment site in Minnesota. Other areas of activity include screening studies for other potential sites and an in-house project to advance the use of chemicals with the hot-water displacement.

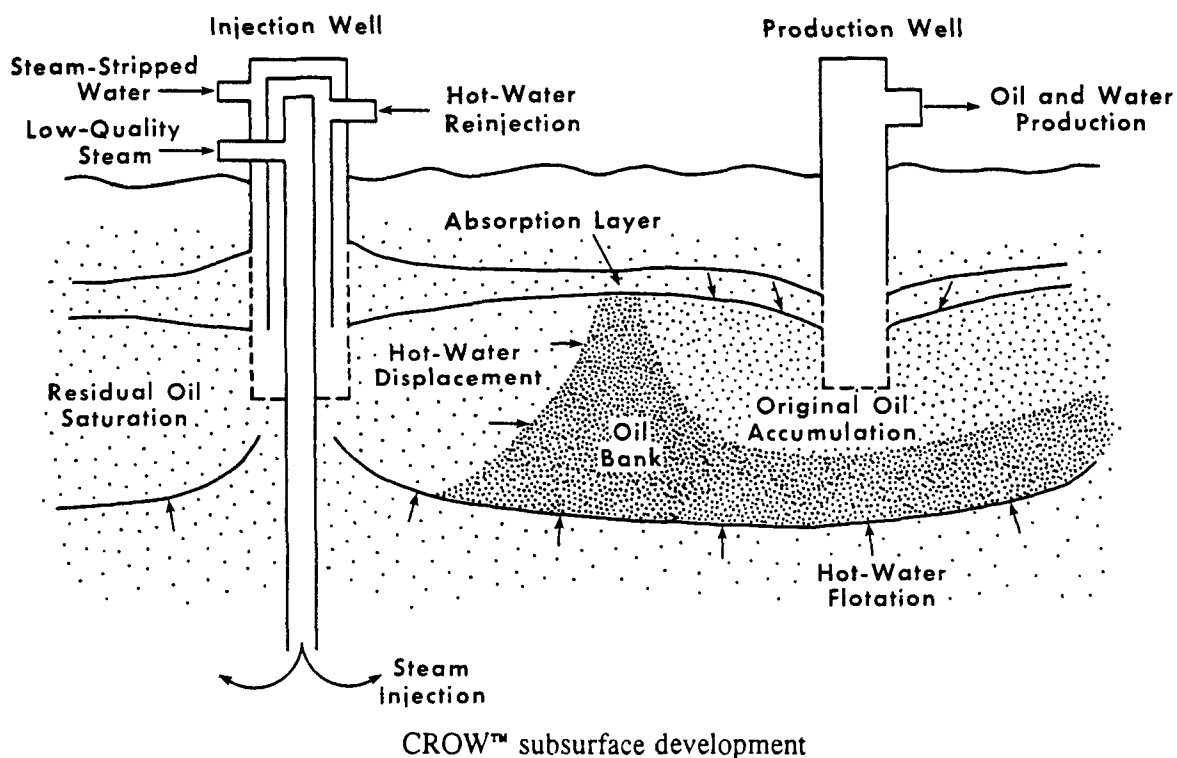
### Remediation Costs

No cost information is available.

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## Debris Washing System

### Organics, PCBs, Pesticides, and Inorganics in Debris

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#### Technology Description

This technology was developed by EPA's Risk Reduction Engineering Laboratory (RREL) staff and IT Corporation to decontaminate debris currently found at Superfund sites throughout the country. The pilot-scale debris washing system (DWS) was demonstrated under the SITE Program.

The DWS consists of 300-gallon spray and wash tanks, surfactant and rinse water holding tanks, and an oil-water separator. The decontamination solution treatment system includes a diatomaceous earth filter, an activated carbon column, and an ion exchange column. Other required equipment includes pumps, a stirrer motor, a tank heater, a metal debris basket, and particulate filters. The DWS unit is transported on a 48-foot semitrailer. At the treatment site, the DWS unit is assembled on a 25-by-24-foot concrete pad and enclosed in a temporary shelter.

A basket of debris is placed in the spray tank with a forklift, where it is sprayed with an aqueous detergent solution. High-pressure water jets blast contaminants and dirt from the debris. Detergent solution is continually recycled through a filter system that cleans the liquid.

The wash and rinse tanks are supplied with water at 140°F, at a pressure of 60 pounds per square inch gauge (psig). The contaminated wash solution is collected and treated prior to discharge. An integral part of the technology involves treating the detergent solution and rinse water to reduce the contaminant concentration to allowable discharge levels. Process water treatment consists of particulate filtration, activated carbon adsorption, and ion exchange. Approximately 1,000 gallons of liquid are used during the decontamination process.

The DWS can be applied on site to various types of debris (metallic, masonry, or other solid debris) contaminated with hazardous chemicals, such as pesticides, polychlorinated biphenyls (PCB), lead, and other metals.

#### Technology Performance

The first pilot-scale test was performed at EPA's Region 5 Carter Industrial Superfund site in Detroit, Michigan. PCB reductions averaged 58 percent in batch 1 and 81 percent in batch 2. Design changes were made and tested on the unit before additional field testing.

Field testing was conducted using an upgraded pilot-scale DWS at a PCB-contaminated Superfund site in Hopkinsville, Kentucky (EPA Region 4), during December 1989. PCB levels on the surfaces of metallic transformer casings were reduced to less than or equal to 10 micrograms PCB per 100 square centimeters. All 75 contaminated transformer casings on site were decontaminated to EPA cleanup criteria and sold to a scrap metal dealer.

The DWS was also field tested at another Superfund site in Region 4, the Shaver's Farm site in Walker County, Georgia. The contaminants of concern were benzonitrile and dicamba. After being cut into sections, 55-gallon drums were placed in the DWS and carried through the decontamination process. Benzonitrile and dicamba levels on the surfaces of drums were reduced from the average pretreatment concentrations of 4,556 and 23 micrograms (µg) per 100 square centimeters to average concentrations of 10 and 1 µg/100 square centimeters, respectively.

Results have been published in a Technology Evaluation Report (EPA/540/5-91/006a) entitled

## "Design and Development of a Pilot-Scale Debris Decontamination System."

Further development of this technology by RREL and IT Corporation includes design, development, and demonstration of a full-scale mobile version of the DWS.

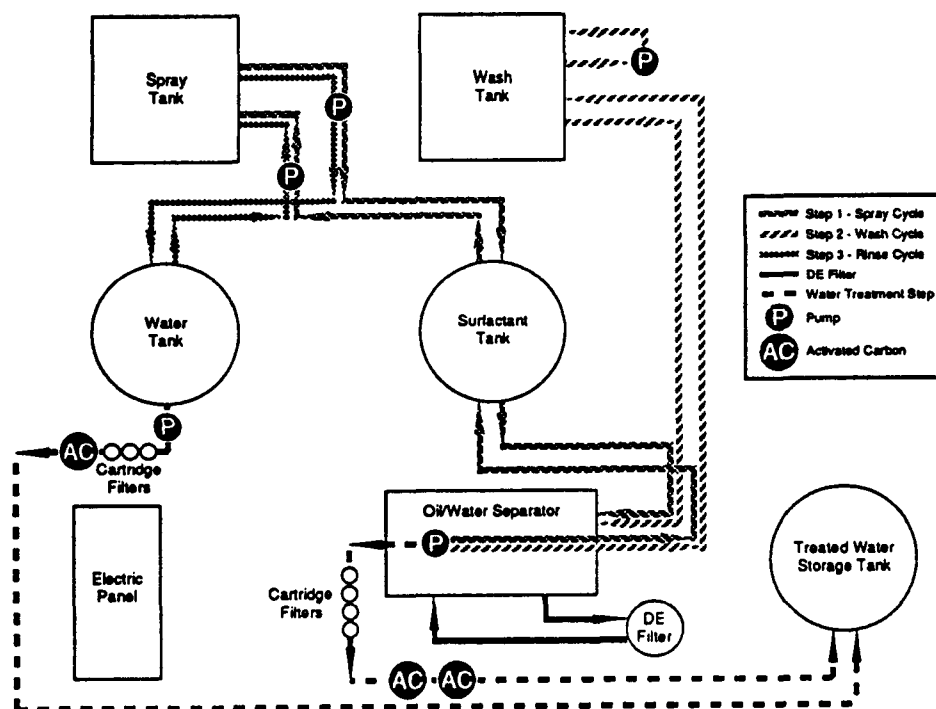
### Remediation Costs

Cost information is not available.

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Schematic of the pilot-scale debris washing system.



### Soil Restoration Unit

PCBs, PCPs, Creosote, Chlorinated Solvents, Naphthalene,  
Diesel Oil, Used Motor Oil, Jet Fuel, Grease, and Organic Pesticides in Soil

#### Technology Description

The soil restoration unit is a mobile solvent extraction remediation device for the on-site removal of organic contaminants from soil. Extraction of soil contaminants is performed with a mixture of organic solvents in a closed loop, counter-current process that recycles all solvents. Terra-Kleen Corporation uses a combination of up to 14 solvents, each of which can dissolve specific contaminants in the soil and can mix freely with water. None of the solvents is a listed hazardous waste, and the most commonly used solvents are approved by the Food and Drug Administration as food additives for human consumption. The solvents are typically heated to efficiently strip the contaminants from the soil. Contaminated soil is fed into a hopper, and then transported into the soil and solvent slurry modules. In the modules, the soil is continually leached by clean solvent. The return leachate from the modules is monitored for contaminants so that the soil may be retained within the system until any residual contaminants within the soil are reduced to targeted levels. Terra-Kleen Corporation offers "hotspot protection" in which real-time monitoring of the contaminant levels alleviates the problems of treating localized higher contaminant areas of soil.

The leachate from the soil and solvent modules is stripped of contaminants by distillation in combination with activated charcoal filtering. High boiling point materials extracted from the soil stay in the bottoms of the distillation columns, and are periodically flushed from the system into labeled 55-gallon drums for off-site disposal. The distillate from the columns is sent through an activated charcoal filter to remove the lower boiling point contaminants from the

solvent. The clean solvent is then reused in the system, completing the closed solvent loop.

The soil and solvent slurry, which has had the contamination reduced to its desired levels, is then sent to a closed loop dryer system that removes the solvent from the soil. The solvent vapors in the dryer are monitored with an organic vapor monitor that indicates when the solvent has been removed so the soil can leave the system.

Terra-Kleen Corporation's technology is particularly effective in removing polychlorinated biphenyls (PCB), pentachlorophenol (PCP), creosote, chlorinated solvents, naphthalene, diesel oil, used motor oil, jet fuel, grease, organic pesticides, and other organic contaminants in soil. It has not been tested using contaminated sediments and sludges as feed stock.

#### Technology Performance

The soil restoration unit has been used for remediation of the Treban Superfund site. Results from that site are shown below:

Test	Initial PCB Concentration (ppm)	Final PCB Concentration (ppm)	Required Number of Passes	Percent Reduction
A	740	77	1	90
B	810	3	1	99+
C	2,500	93	4	96

The unit has also been used under an EPA Toxic Substance Control Act (TSCA) Research & Development (R&D) permit as part of the approval process for a nationwide transportable treatment permit for PCB destruction. In the test, PCB in soil was reduced from a maximum of 200 ppm to a final composite of 2.8 ppm.

Spiked soil, with contamination levels of up to 2,200 ppm PCB, was remediated to PCB levels of 12 ppm. Since this test, system modifications have been added to improve removal efficiencies.

Demonstration of the full-scale unit under the SITE Demonstration Program is pending the selection of a site.

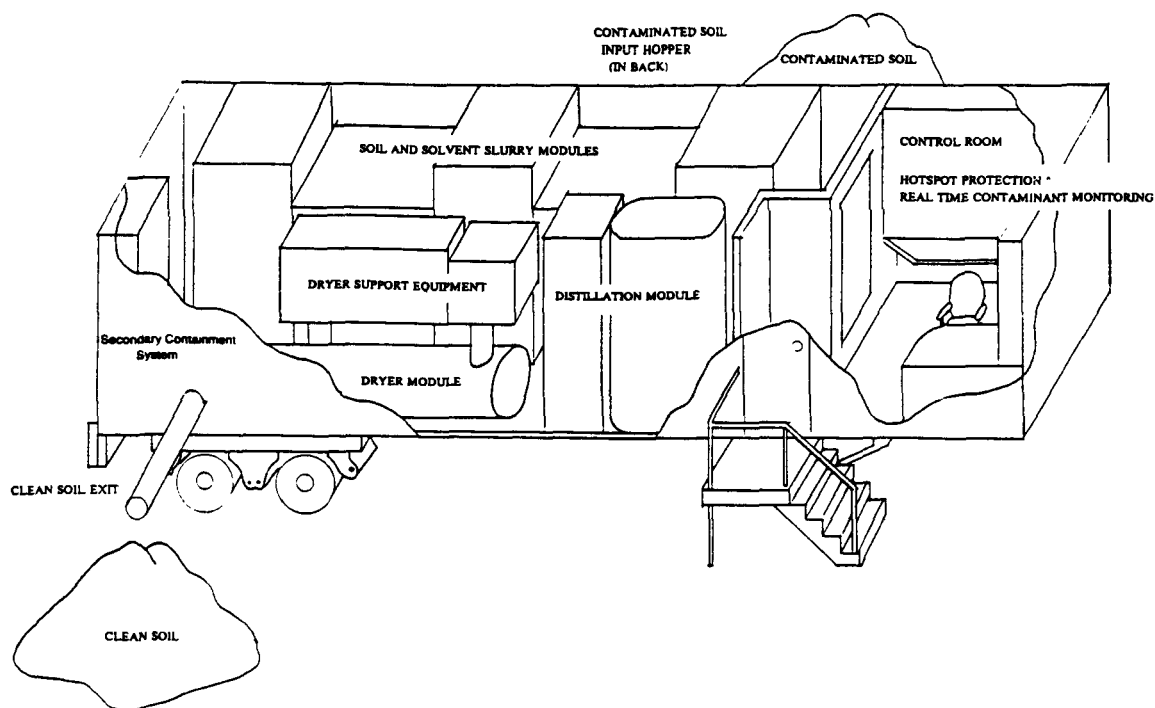
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## Remediation Costs

No cost information is available.



Soil restoration unit



## Soil Treatment with Extraksol™ Semi-VOCs, PCBs, PCPs, and PAHs in Soil

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### Technology Description

Extraksol™ is a solvent extraction technology on a modular transportable system. This batch process extracts organic contaminants from the soil using proprietary nonchlorinated, organic solvents. The solvents are regenerated by distillation, and the contaminants are concentrated in the distillation residues.

The three treatment steps — soil washing, soil drying, and solvent regeneration — occur on a flatbed trailer for the smaller unit (1 ton/hour) and on a skid-mounted rig for the larger unit (3 to 6 tons/hour). The extraction fluid (solvent) is circulated through the contaminated matrix within an extraction chamber to wash the soil. Controlled temperature and pressure optimize the washing procedure. Hot inert gas dries the soil. The gas vaporizes the residual extract fluid and carries it from the extraction chamber to a condenser, where the solvent is separated from the gas. The solvent-free gas is reheated and reinjected into the soil, as required, for complete drying. After the drying cycle, the decontaminated soil may be returned to its original location.

Distillation of the contaminated solvent achieves two major objectives: (1) it minimizes the amount of solvent required to perform the extraction, by regenerating it in a closed loop, and (2) it significantly reduces the volume of contaminants requiring further treatment or off-site disposal by concentrating them in the still bottoms.

The process extracts organic contaminants from solids. It is capable of extracting a range of contaminants, including polychlorinated

biphenyls (PCB), pentachlorophenol (PCP), polycyclic aromatic hydrocarbons (PAH), monocyclic aromatic hydrocarbon (MAH), pesticides, oils, and hydrocarbons. The process has the following soil restrictions:

- A maximum clay fraction of 40 percent
- A maximum water content of 30 percent
- A maximum size, if porous material, of approximately 2 inches (preferably 1/4 inch or smaller)
- A maximum size, if nonporous material, of 1 to 2 feet, but the maximum size is not recommended. Rather, particles with a diameter of 4 inches or less are preferred.

The process can also extract volatile contaminants, such as gasoline and solvents, through stripping and condensation.

### Technology Performance

The process has been tested in several pilot projects on a range of contaminants. This technology was accepted into the SITE Demonstration Program in June 1990. The unit will be used to decontaminate 3,500 tons of PCB-contaminated soil in Washburn, Maine, in 1992.

### Remediation Costs

No cost information is available.

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## Soil Washer for Radioactive Soil Radionuclides in Soils

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### Technology Description

This technology is designed to reduce the volume of soils contaminated with low concentrations of radionuclides. The process is used with soils in which radioactivity is concentrated in the fine soil particles and in friable coatings around the larger particles.

The soil washer uses attrition mills to liberate the contaminated coatings and then uses hydroclassifiers to separate the contaminated fines and coatings. Next, a filter press dewateres the contaminated portion in preparation for offsite disposal. The clean portion remains on site, reducing the high costs of transporting and burying large volumes of low-level radioactive soil.

### Technology Performance

This technology completed the first round of testing with soil from the Montclair Superfund site in New Jersey. The result was a 30 percent volume reduction of nine picoCuries per gram soil, with the clean portion at six picoCuries per gram soil. The pilot soil washing plant also achieved a steady-state operation for three hours at the rate of approximately 1.5 tons per hour. The plant is now being optimized in preparation for the second round of testing.

This process was developed as part of EPA's Volume Reduction/Chemical Extraction (VORCE) Program which also involves laboratory screening and bench-scale testing of soils for active Department of Energy sites. These include the Nevada Test Site, Hanford Reservation, Idaho National Engineering Laboratory, Rocky Flats, the Fernald Plant, and two other New Jersey sites that are part of

DOE's Formerly Utilized Site Remedial Action Program (FUSRAP).

### Remediation Costs

Disposal and transportation cost for radioactive soils is about \$900 per cubic yard. Based on the first round of testing of the pilot soil washing plant, volume reduction at a rate of about 1.5 cubic yards per hour has an operational cost of about \$300 per hour.

### General Site Information

This technology is being tested for the Montclair and the West Orange and Glen Ridge Superfund sites, both in New Jersey.

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## Soil Washing Metals in Oxidation Lagoons

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### Technology Description

In this process, soil is treated with a wash reagent that facilitates the transfer of contaminants, primarily heavy metals and arsenic, from the soil to the wash liquid. The wash liquid then will be neutralized with a caustic to precipitate the metals from the solution. The precipitated metals will be disposed of in a landfill.

### Technology Performance

Full-scale remediation of 12,000 cubic yards of soil at the Sacramento (California) Army Depot are scheduled to begin in mid-1992 and last approximately three months. The soil has been found to be contaminated to a depth of 18 inches. Primary contaminants are cadmium, nickel, lead, and copper.

### Remediation Costs

Cost information is not available.

### General Site Information

This remediation project involves a group of four contaminated oxidation lagoons at the Sacramento Army Depot in California. The lagoons currently are not in use and are covered partially with vegetation. Three drainage ditches and a dry section of a nearby creek also have been contaminated from spillover from the lagoons following rainstorms.

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## **Soil Washing/Catalytic Ozone Oxidation SVOCs, PCBs, PCP, Pesticides, Dioxin, and Cyanide in Soil, Sludge, and Ground Water**

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### **Technology Description**

The Excalibur technology is designed to treat soils with organic and inorganic contaminants. The technology is a two-stage process: the first stage extracts the contaminants from the soil, and the second stage oxidizes contaminants present in the extract. The extraction is carried out using ultrapure water and ultrasound. Oxidation involves the use of ozone, and ultraviolet light. The treatment products of this technology are decontaminated soil and inert salts.

After excavation, contaminated soil is passed through a 1-inch screen. Soil particles retained on the screen are crushed using a hammermill and sent back to the screen. Soil particles passing through the screen are sent to a soil washer, where ultrapure water extracts the contaminants from the screened soil. Ultrasound acts as a catalyst to enhance soil washing. Typically, 10 volumes of water are added per volume of soil, generating a slurry of about 10 to 20 percent solids by weight. This slurry is conveyed to a solid/liquid separator, such as a centrifuge or cyclone, to separate the decontaminated soil from the contaminated water. The decontaminated soil can be returned to its original location or disposed of appropriately.

After the solid/liquid separation, any oil present in the contaminated water is recovered using an oil/water separator. The contaminated water is ozonated prior to oil/water separation to aid in oil recovery. The water then flows through a filter to remove any fine particles. After the particles are filtered, the water flows through a carbon filter and a deionizer to reduce the contaminant load on the multichamber reactor. In the multichamber reactor, ozone gas,

ultraviolet light, and ultrasound are applied to the contaminated water. Ultraviolet light and ultrasound catalyze the oxidation of contaminants by ozone. The treated water (ultrapure water) flows out of the reactor to a storage tank and is reused to wash another batch of soil. If makeup water is required, additional ultrapure water is generated on site by treating tap water with ozone and ultrasound.

The treatment system is also equipped with a carbon filter to treat the off-gas from the reactor. The carbon filters are biologically activated to regenerate the spent carbon in situ.

System capacities range from one cubic foot of solids per hour, (water flow rate of one gallon per minute), to 27 cubic yards of solids per hour, (with a water flow rate of 50 gallons per minute). The treatment units available for the SITE demonstration can treat 1 to 5 cubic yards of solids per hour.

This technology can be applied to soils, solids, sludges, leachates, and ground water containing organics such as polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), pesticides and herbicides, dioxins, and inorganics, including cyanides. The technology could effectively treat total contaminant concentrations ranging from 1 part per million (ppm) to 20,000 ppm. Soils and solids greater than 1 inch in diameter need to be crushed prior to treatment.

## Technology Performance

The Excalibur technology was accepted into the SITE Demonstration Program in July 1989. The Coleman-Evans site in Jacksonville, Florida, has been tentatively scheduled for a SITE demonstration. This project is currently on hold.

## Remediation Costs

No cost information is available.

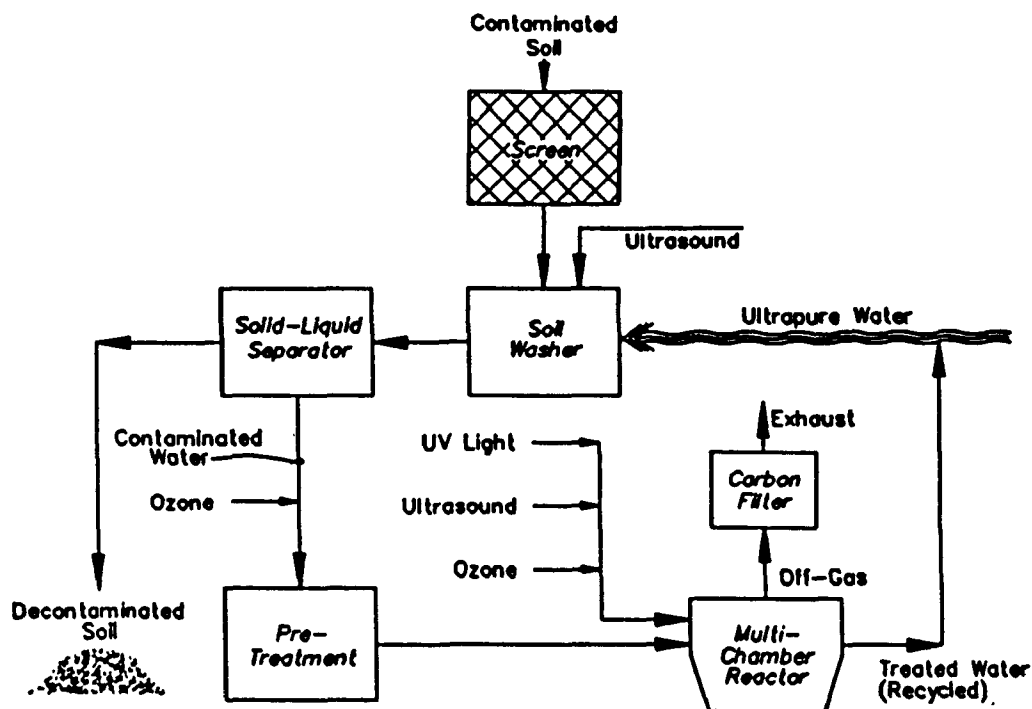
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Excalibur treatment system flow diagram



## Soil Washing System

### PAHs, PCBs, PCP, Pesticides, and Metals in Soil

#### Technology Description

The BioTrol Soil Washing System is a patented, water-based, volume reduction process for treating excavated soil. Soil washing may be applied to contaminants concentrated in the fine-size fraction of soil (silt, clay, and soil organic matter) and the mainly surficial contamination associated with the coarse (sand and gravel) soil fraction. The goal is for the soil product to meet appropriate cleanup standards.

After debris is removed, soil is mixed with water and subjected to various unit operations common to the mineral processing industry. Process steps can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering operations.

The core of the process is a multi-stage, counter-current, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates soil aggregates, freeing contaminated fine particles from the coarser sand and gravel. In addition, surficial contamination is removed from the coarse fraction by the abrasive scouring action of the particles themselves. Contaminants may also be solubilized, as dictated by solubility characteristics or partition coefficients.

The contaminated residual products can be treated by other methods. Process water is normally recycled after biological or physical treatment. Options for the contaminated fines include off-site disposal, incineration, stabilization, and biological treatment.

This technology was initially developed to clean soils contaminated with wood preserving wastes such as polycyclic aromatic hydrocarbons

(PAH) and pentachlorophenol (PCP). The technology may also be applied to soils contaminated with petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCB), various industrial chemicals, and metals.

#### Technology Performance

The SITE demonstration of the soil washing technology took place from September 25 to October 30, 1989, at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. A pilot-scale unit with a treatment capacity of 500 pounds per hour was operated 24 hours per day during the demonstration. Feed for the first phase of the demonstration (2 days) consisted of soil contaminated with 130 parts per million (ppm) PCP and 247 ppm total PAHs. During the second phase (7 days), soil containing 680 ppm PCP and 404 ppm total PAHs was fed to the system.

Contaminated process water from soil washing was treated biologically in a fixed-film reactor and was recycled. A portion of the contaminated fines generated during soil washing was treated biologically in a three-stage, pilot-scale EIMCO Biolift® reactor system supplied by the EIMCO Process Equipment Company.

The Technology Evaluation Report (TER) and the Applications Analysis Report (AAR) are expected to be available in 1992.

Following is a summary of the results of the demonstration of this technology:

- Feed soil (dry weight basis) was successfully separated into 83 percent washed soil, 10 percent woody residues, and 7 percent fines. The washed soil retained

about 10 percent of the feed soil contamination; while 90 percent of the feed soil contamination was contained within the woody residues, fines and process wastes.

- The soil washer achieved up to 89 percent removal of PCPs and 88 percent of total PAHs, based on the difference between parts per million (ppm) levels in the contaminated (wet) feed soil and the washed soil.
- The system degraded up to 94 percent of PCP in the process water from soil washing. PAH removal could not be determined due to low influent concentrations.

### Remediation Costs

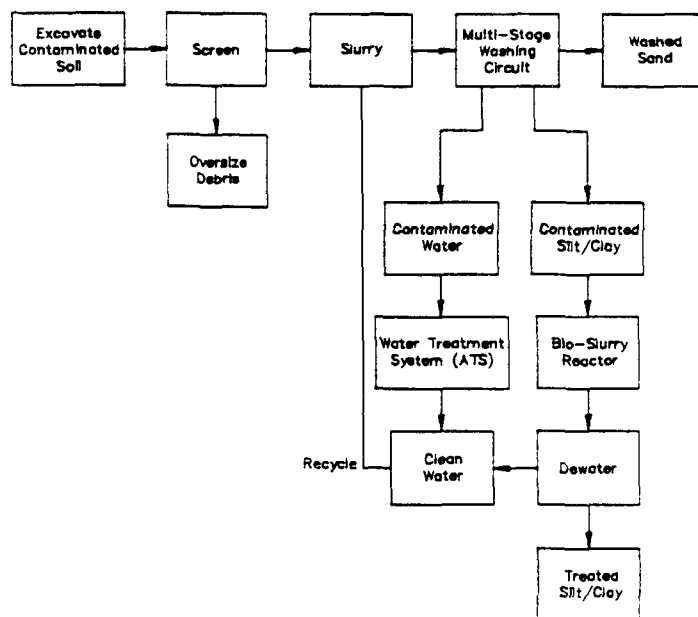
Cost of a commercial-scale soil washing system, assuming use of all three technologies, was estimated to be \$168 per ton. Incineration of woody material accounts for 76 percent of the cost.

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BioTrol Soil washing System process diagram



## **Solvent Extraction**

### **PCBs, VOCs, SVOCs, and Petroleum Wastes in Soil and Sludge**

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#### **Technology Description**

CF Systems Corporation technology uses liquified gases as solvent to extract organics from sludges, contaminated soils, and wastewater. Propane is the solvent typically used for sludges and contaminated soils, while carbon dioxide is used for wastewater streams. The system is available as either a continuous flow unit for pumpable wastes or a batch system for dry soils.

Contaminated solids, slurries, or wastewaters are fed into the extractor along with solvent. Typically, more than 99 percent of the organics are extracted from the feed. Following phase separation of the solvent and organics, treated water is removed from the extractor while the mixture of solvent and organics passes to the solvent recovery system. In the solvent recovery system, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off and either reused or disposed of.

The extractor design is different for contaminated wastewaters and semisolids. For wastewaters, a tray tower contactor is used and for solids and semisolids, a series of extractor/decanter are used.

This technology can be applied to soils and sludges containing volatile and semivolatile organic compounds and other higher boiling complex organics, such as polychlorinated biphenyls (PCB), dioxins, and pentachlorophenols (PCP). Also, this process can treat refinery wastes and organically contaminated wastewater.

#### **Technology Performance**

The pilot-scale system was tested on PCB-laden sediments from the New Bedford (Massachusetts) Harbor Superfund site during September 1988. PCB concentrations in the harbor ranged from 300 parts per million (ppm) to 2,500 ppm. The Technology Evaluation Report (EPA/540/5-90/002) and the Applications Analysis Report (EPA/540/A5-90/002) were published in August 1990.

Following is a summary of the applications analysis:

- Extraction efficiencies of 90 to 98 percent were achieved on sediments containing between 360 and 2,575 ppm PCBs. PCB concentrations were as low as 8 ppm in the treated sediment.
- In the laboratory, extraction efficiencies of 99.9 percent have been obtained for volatile and semivolatile organics in aqueous and semi-solid wastes.
- Operating problems included solids being retained in the system hardware and foaming in receiving tanks. The vendor identified corrective measures to be implemented in the full-scale commercial unit.
- Projected costs for PCB cleanups are estimated at approximately \$150 to \$450 per ton, including material handling and pre- and post-treatment costs. These costs are highly sensitive to the utilization factor and job size, which may result in lower costs for large cleanups.

This technology was demonstrated concurrently with dredging studies managed by the U.S. Army Corps of Engineers. Contaminated sediments were treated by the CF Systems Pit Clean-up Unit, using a liquified propane and butane mixture as the extraction solvent.

Extraction efficiencies were high, despite some operating difficulties during the tests. Development of full-scale commercial systems has eliminated problems associated with cross-contamination in the pilot plant design.

A full-scale commercial system is currently operating under contract at a major Gulf Coast refinery treating refinery K-wastes to meet best demonstrated available technology (BDAT) standards for solids disposal. The unit has operated at better than 85 percent since acceptance in early March 1991. Treatment costs are competitive with all other on-site treatment processes.

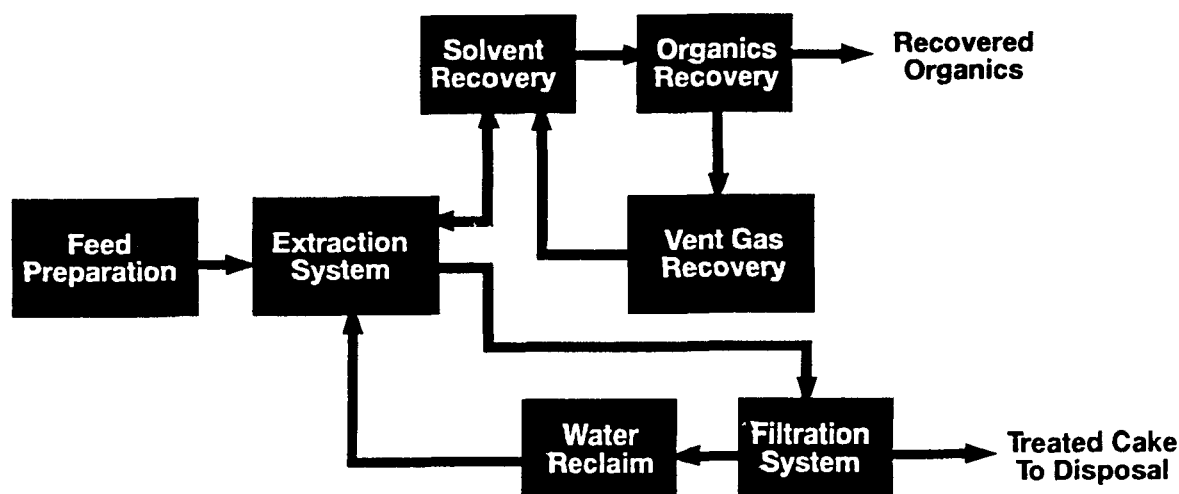
Commercial systems have been sold to Clean Harbors, Braintree, Massachusetts, for wastewater cleanup; and ENSCO of Little Rock, Arkansas, for incinerator pretreatment. The

startup of the Clean Harbors wastewater unit began late in 1991. The technology has been selected by EPA and Texas Water Commission on a "sole source" basis for clean up of the 80,000 cubic yard United Creosoting site at Conroe, Texas.

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CF systems solvent extraction remediation process

## **Other Physical Treatment**



## Advanced Oxidation Process VOCs in Ground Water

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### Technology Description

This technology uses the oxidative power of the advanced oxidation processes (AOPs) to destroy ordnance contaminants in ground water. The AOPs involve using ultraviolet (UV) radiation, hydrogen peroxide, and ozone in various combinations to produce hydroxyl radicals to destroy the target organics. Although UV, hydrogen peroxide, and ozone have oxidative power individually, the primary oxidative power in the AOP reactions are from the hydroxyl radicals.

Laboratory studies both in formal laboratory setting and in commercial vendor shops were conducted to determine the capabilities of the AOP reactions available currently to destroy low-level ordnance contaminants in ground water. The treatment goals were to reach treatment criteria for ordnance compounds specified in Washington State regulations. Laboratory findings indicated that the best AOP option is UV/ozone which can treat the ground water to meet specified treatment criteria: 2.9 µg/L for TNT and 0.8 µg/L for RDX. Because the oxidation of ordnance compounds can result in production of more toxic by-products, studies are being conducted to avoid undesirable results.

The organics targeted in this effort are TNT and RDX, the most frequently found and persistent components of ordnance contamination. Contamination is the result of past ordnance-related disposal practices. As these organics are not readily soluble, their concentrations in contaminated ground water are typically low. However, their presence in the drinking water supply aquifer presents a health threat and is closely regulated.

### Technology Performance

A field technology demonstration is scheduled for the Fall of 1992 at Bangor SUBASE in Washington. At the conclusion of the field tests, a full-scale system will be designed for treating the ground water as part of the effort to contain the migrating plume. The pump and treat effort is a part of the Interim Remedial Action for the Bangor site.

### Remediation Costs

No cost information is available at this time.

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## Advanced Oxidation Process VOCs in Ground Water

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### Technology Description

This technology employs the oxidative power of the different advanced oxidation processes (AOPs) to destroy organic contaminants in ground water. The AOPs involve using ultraviolet (UV) radiation, hydrogen peroxide, and ozone in various combinations to generate hydroxyl radicals to destroy the target organics. Although UV, hydrogen peroxide, and ozone have oxidative power individually, the hydroxyl radical reactions are the most important.

Based on laboratory study findings, a two-staged approach was developed for an on-site demonstration of the AOP technology. This approach exploited the varied reaction conditions of different AOPs to optimize the organics destruction efficiency. The two stages involved first applying ozone/peroxide at high pH and secondly ozone/UV at low pH. A third stage using peroxide/UV was also tested as a polishing stage and to provide added assurance for a clean discharge.

This technology demonstration was targeted at treating ground water contaminated with organic pollutants from past fire fighting exercises. The pollutants came from aqueous film foam (AFFF, a fire fighting agent), various fuels, and other combustible materials used in the exercises. The pollutants detected included chlorinated hydrocarbons and fuel components. The contaminant concentrations in the ground water ranged from 50 to 100 ppm measured as Total Organic Carbon (TOC).

### Technology Performance

The on-site technology demonstration was completed in 1991 at a U.S. Navy site in Lakehurst, NJ. It was demonstrated that the AOP was effective in the destruction of individual

contaminants as well as TOC, and that a one-stage AOP system may be adequate for trace contaminant removal.

### Remediation Costs

No cost information is available at this time.

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## **Carver-Greenfield® Process**

### **PCBs, Dioxin, and Oily Wastes in Soil and Sludge**

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#### **Technology Description**

The Carver-Greenfield Process® is designed to separate materials into their constituent solid, oil (including oil-soluble substances), and water phases. It is intended mainly for soils and sludges contaminated with oil-soluble hazardous compounds. The technology uses a food-grade carrier oil to extract the oil-soluble contaminants. Pretreatment is necessary to achieve particle sizes of less than ¼ inch.

The carrier oil, with a boiling point of 400 degrees Fahrenheit, is typically mixed with waste sludge or soil, and the mixture is placed in an evaporation system to remove any water. The oil serves to fluidize the mix and maintain a low slurry viscosity to ensure efficient heat transfer, allowing virtually all of the water to evaporate.

Oil-soluble contaminants are extracted from the waste by the carrier oil. Volatile compounds present in the waste are also stripped in this step and condensed with the carrier oil or water. After the water is evaporated from the mixture, the resulting dried slurry is sent to a centrifuging section that removes most of the carrier oil and contaminants from the solids.

After centrifuging, residual carrier oil is removed from the solids by a process known as "hydroextraction." The carrier oil is recovered by evaporation and steam stripping. The hazardous constituents are removed from the carrier oil by distillation. This stream can be incinerated or reclaimed. In some cases, heavy metals in the solids will be complexed with hydrocarbons and will also be extracted by the carrier oil.

The Carver-Greenfield Process® can be used to treat sludges, soils, and other water-bearing

wastes containing oil-soluble hazardous compounds, including polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), and dioxins. The process has been commercially applied to municipal wastewater sludge, paper mill sludge, rendering waste, pharmaceutical plant sludge, and other wastes.

#### **Technology Performance**

The demonstration of this technology was completed in August 1991, at EPA's Edison, New Jersey, research facility. Petroleum wastes (drilling muds) from the PAB oil site in Abbeville, Louisiana, were used for the demonstration.

Preliminary results indicate a successful separation of oily drilling muds into their constituent oil, water, and solid phases. Laboratory analysis on process residuals was conducted during the late summer and fall 1991.

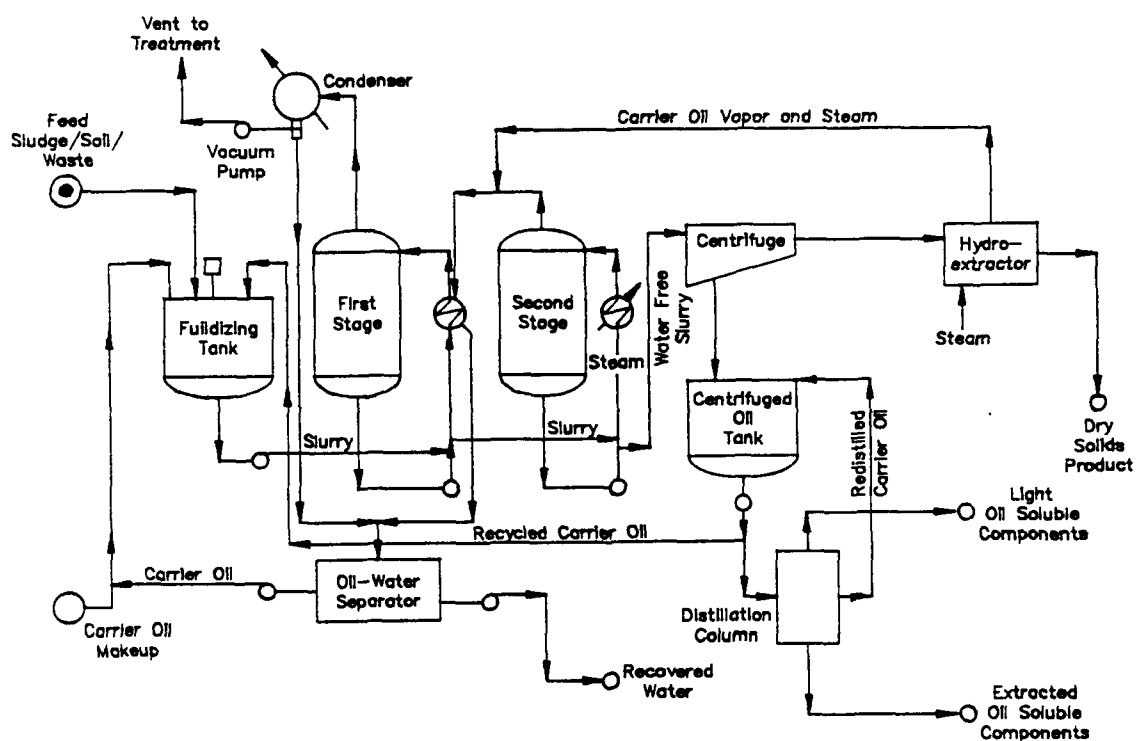
#### **Remediation Costs**

No cost information is available.

#### **Contacts**

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Carver-Greenfield® process schematic



## Catalytic Decontamination

### Volatile Organic Compounds (VOC) in Ground Water

#### Technology Description

This catalytic decontamination process is a closed system that treats volatile organic compounds in ground water producing innocuous end products. This technology can be useful when cross-media transfer of the contamination, which may occur with other processes, such as air stripping, is unacceptable. This technology is primarily a ground-water restoration technique, although surface water can be treated as well. It is especially applicable for highly contaminated waters such as leachates.

The ULTROX system used in the pilot study consists of two "loops." The first loop consists of air drying, ozone generation, and injection of the ozone into the vapor-liquid contact tank. Air effluent passes through a catalytic destruction unit and returns to the air drier. The second loop is open and consists of a water inlet from the ground-water source, pretreatment, introduction into the vapor-liquid contact tank, and discharge. The water pretreatment might consist of filtering, water softening, iron removal, or defoaming.

This technology has a number of advantages:

- The process is closed circuit, i.e., there is no air effluent;
- It operates at negative air pressure, thus, reducing the risk of accidental contamination due to leaks; and
- It is a destructive, rather than a cross-media transfer technique.

Despite these advantages, this technology also has limitations:

- The method might not be cost effective with respect to methods that have air effluents;
- When treating high concentrations, a potentially large consumption of ozone will result;
- When treating anoxic leachates, reduced metal compounds are likely to be present;
- These reduced metal compounds will react with the ozone and can form insoluble precipitates as well as result in large ozone consumption;
- The metal precipitates could require extensive system cleaning;
- The method requires considerable energy for the generation of UV light, dry air, ozone, pumps, and blowers; and
- Biofouling can occur on the UV light tubes.

#### Technology Performance

The results from a small-scale pilot test conducted at Fort Dix, New Jersey were both positive and negative:

- Although total organic carbon concentration was not reduced, the concentration of volatile halogenated organics (VHO) was reduced up to 90 percent; and
- Without the inclusion of UV light in the treatment, the VHO concentration was reduced, but methylene chloride was not affected and dichloroethanes were not reduced below detection limits.

## **Remediation Costs**

Based on limited experience to date, the operating and maintenance costs of this method have not been developed in detail, but are expected to be in the range of \$1 to \$8 per 1,000 gallons, depending upon the concentration of the contaminants and the amount of pretreatment required. Uninstalled equipment for treating 50,000 gpd of ground water, with an organic halide concentration in the range of 75 to 100 g/L, would cost in the range of \$150,000 to \$200,000.

## **General Site Information**

A small-scale pilot testing (1 to 10 drums) has been conducted at Fort Dix, New Jersey.

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## **Entrained-Bed Gasification**

### **Organics in Soils, Sludges, and Sediments**

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#### **Technology Description**

The Texaco entrained-bed gasification process is a non-catalytic partial oxidation process in which carbonaceous substances react at elevated temperatures to produce a gas containing mainly carbon monoxide and hydrogen. This product, called synthesis gas, can be used (1) to produce other chemicals or (2) to be burned as fuel. Ash in the feed melts and is removed as a glass-like slag. The treatment of hazardous waste materials in a gasifier is an extension of Texaco's conventional gasification technology, which has been operated commercially for over 30 years, using widely varying feedstocks, such as natural gas, heavy oil, coal, and petroleum coke.

The process treats waste material at pressures above 20 atmospheres and temperatures between 2,200 and 2,800 degrees Fahrenheit.

Wastes are pumped in a slurry form to a specially designed burner mounted at the top of a refractory-lined pressure vessel. The waste feed, along with oxygen and an auxiliary fuel such as coal, flow downward through the gasifier to a quench chamber that collects the slag for removal through a lock hopper. The synthesis gas is then further cooled and cleaned by a waste scrubbing system; a sulfur recovery system may be added. Fine particulate matter removed by the scrubber may be recycled back to the gasifier.

The cooled, water-scrubbed product gas is mainly composed of hydrogen and carbon monoxide, but no hydrocarbons heavier than methane. Metals and other ash constituents become part of the inert slag.

The capacity of a system suitable for on-site waste destruction is based on a wet synthesis

gas production rate of 3 million standard cubic feet per day. Depending on the heat content and proximate analysis, approximately 12 to 24 tons per day of hazardous waste can potentially be treated.

This process can treat contaminated soils, sludges, and sediments containing both organic and inorganic constituents, such as used motor oils and lubricants, chemical wastes, and petroleum residues. Solids in the feed must be ground and pumped in a slurry form containing 40 to 70 percent solids by weight and 60 to 30 percent liquid, usually water.

#### **Technology Performance**

This technology was accepted into the SITE Demonstration program in July 1991. A demonstration with Superfund hazardous waste is planned for 1992 at Texaco's Montebello Research Laboratory. In December 1988, under a grant from the California Department of Health Services, Texaco demonstrated the gasification of low heating-value petroleum tank bottoms to produce synthesis gas and nonhazardous effluents. During a 40-hour pilot run, this hazardous material was used as a supplemental feed to a coal-fired gasifier. Carbon conversion in the waste stream was over 99 percent, and solid residues from the process were determined to be nonhazardous, based on California Assessment Manual limits for total and leachable materials. Both wastewater and solid residue were determined to be free of trace organics and EPA priority pollutants.

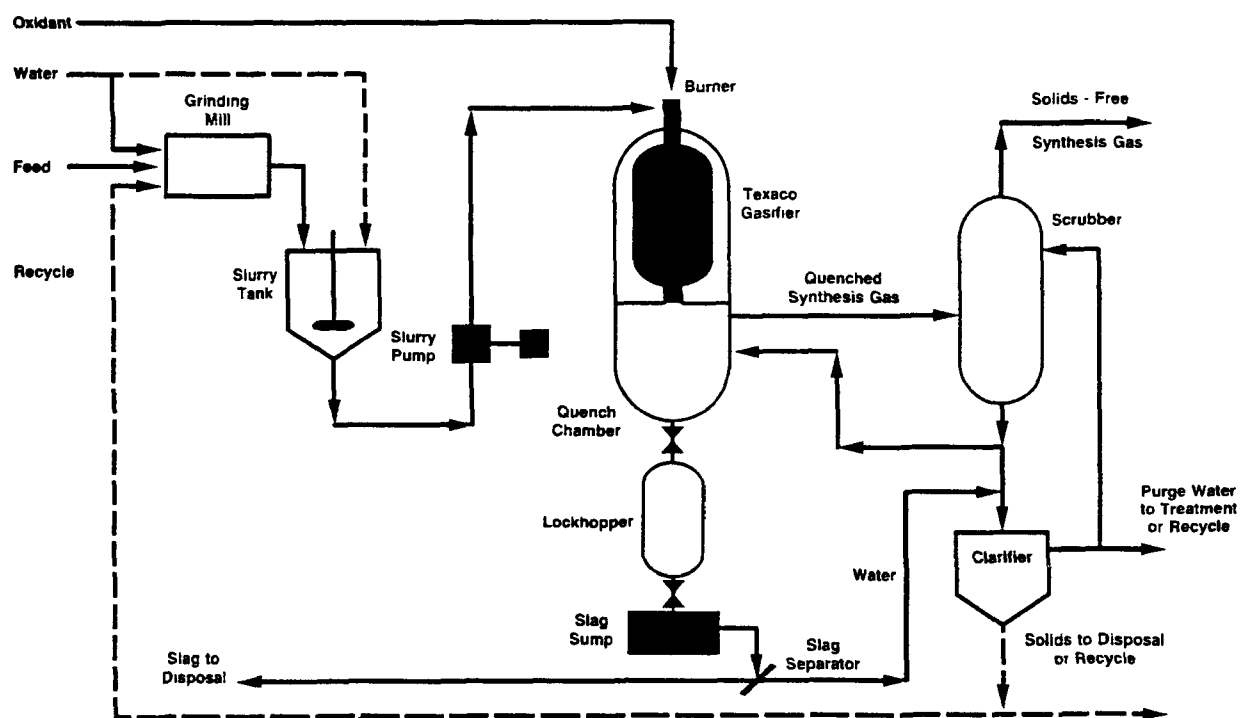
## Remediation Costs

No cost information is available.

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Schematic diagram of the entrained-bed gasification process



## **Filtration**

### **Heavy Metals and Radionuclides in Ground water**

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#### **Technology Description**

A colloid filter method, filtration process removes inorganic heavy metals and non-tritium radionuclides from industrial wastewater and ground water. The filter unit has an inorganic, insoluble filter bed material (Filter Flow-1000) contained in a dynamic, flow-through configuration resembling a filter plate. The pollutants are removed from the water via sorption, chemical complexing, and physical filtration. By employing site-specific optimization of the water chemistry prior to filtration, the methodology removes the pollutants as ions, colloids, and colloidal aggregates. A three-step process is used to achieve heavy metal and radionuclide removal. First, water is treated chemically to optimize formation of colloids and colloidal aggregates. Second, a prefilter removes the larger particles and solids. Third, the filter bed removes the contaminants to the compliance standard desired. By controlling the water chemistry, water flux rate, and bed volume, the methodology can be used to remove heavy metals and radionuclides in low to high volume waste streams.

The process is designed for either batch or continuous flow applications at fixed installations or field mobile operations. The field unit can be retrofitted to existing primary solids water treatment systems or used as a polishing filter for new installations or on-site remediation applications. Trailer and skid-mounted equipment has been used successfully.

The methodology removes heavy metals and radionuclides from pond water, tank water, ground water, or in-line industrial wastewater treatment systems. The technology also has application for remediation of natural occurring radioactive materials (NORM), man-made low

level radioactive wastes (LLRW) and transuranic (TRU) pollutants.

#### **Technology Performance**

The methodology was accepted into the EPA SITE Demonstration Program in July 1990. EPA and the Department of Energy (DOE) are co-sponsoring the technology evaluation. Bench tests have been conducted at the DOE Rocky Flats Facility, Golden, Colorado, using groundwater samples contaminated with heavy metals and radioactive materials.

#### **Remediation Costs**

No cost information is available.

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## Hydraulic Fracturing Organics and Inorganics in Soil

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### Technology Description

Hydraulic fracturing is a physical process that creates fractures in soils to enhance fluid or vapor flow in the subsurface. The technology places fractures at discrete depths through hydraulic pressurization at the base of a borehole. These fractures are placed at specific locations and depths to increase the effectiveness of treatment technologies, such as soil vapor extraction, in situ bioremediation, and pump-and-treat systems. The technology is designed to enhance remediation in low permeability geologic formations. This technology has been developed for EPA's Risk Reduction Engineering Laboratory by the University of Cincinnati (UC) at the Center Hill facility under the SITE Program.

The fracturing process begins with the injection of a fluid (water) into a sealed borehole until the pressure of the fluid exceeds a critical value and a fracture is nucleated, forming a starter notch. A proppant composed of a granular material (sand) and a viscous fluid (guar gum and water mixture) is then pumped into the fracture as the fracture grows away from the well. After pumping, the proppant grains hold the fracture open while an enzyme additive breaks down the viscous fluid. The resulting fluid is pumped from the fracture, forming a permeable subsurface channel suitable for delivery or recovery of a vapor or liquid.

These fractures function as pathways for vapor extraction or fluid introduction, potentially increasing the effective area available for remediation.

The hydraulic fracturing process is used in conjunction with soil vapor extraction technology to enhance the recovery of contaminated soil vapors. Hydraulically-induced fractures are

used to place fluids and nutrients during in situ bioremediation. The technology has the potential for delivery of solids to the subsurface. Solid compounds useful in bioremediation, such as nutrients or oxygen-releasing compounds, can be injected as granules into the fractures.

Techniques for measuring deformation of the ground surface have been developed for this technology by UC to monitor the position of the fractures in the subsurface.

Hydraulic fracturing is appropriate for enhancing remediation of contaminated soil vapors, soil, and ground water. The technology can be applied to those contaminants or wastes associated with remediation by soil vapor extraction, bioremediation, and pump-and-treat systems.

### Technology Performance

The RREL hydraulic fracturing technology entered the SITE Demonstration Program in July 1991. Pilot-scale feasibility studies have been conducted in Oak Brook, Illinois, and Dayton, Ohio, during July and August 1991, respectively. The hydraulic fracturing process has been integrated with remediation by soil vapor extraction at the Illinois site and with in situ bioremediation at the Ohio site. Additional feasibility study sites are planned. A final full-scale demonstration site will be selected in the near future.

### Remediation Costs

No cost information is available.

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## Hydraulic Soil Mixing

### PCBs, PCP, and Hydrocarbons in Soil and Sludges

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#### Technology Description

Hydraulic Soil Mixing (HSM) is a refinement of a 25-year-old technology used to treat a wide variety of soil problems because of its proven economies. Two to four hydraulic soil mixing injectors are mounted in a line on various carrier vehicles, including forklifts, crawler tractors, and heavy trucks. Each soil mixer is capable of treating a column of waste from 1 to 3 feet in diameter to depths of 40 feet. With current equipment, the system, which is partially patented, can mix and inject solutions of particulate slurry/grouts up to specific gravities of 1.5 to 1.6. Approximately 30 tons of dry solids or 20,000 gallons of slurry can be mixed in situ per injector, per working day. Bottom seals or targeted waste strata can be treated with little disturbance of non-contaminated strata. Various solidification and stabilization materials such as portland cement, fine grind cement, lime, fly ash, and sodium silicates are combined with patented materials such as Trifirmex, MC-500, and MC-100, depending on the number and types of contaminants present. HSM also can be a delivery system for other in situ treatment techniques.

Soils and sludges contaminated with polychlorinated biphenyls (PCB), pentachlorophenol, refinery waste, and hydrocarbons can be treated. Specific concentration ranges that can be treated will depend on the contaminant and its soil and sludge matrix, and will be predetermined by treatability and site characterization studies.

#### Technology Performance

This technology was accepted into the SITE Demonstration program in June 1991. Several pilot-scale and field-scale tests have been conducted on injection of lime and fly ash for

various environmental applications. One application occurred at a large petrochemical plant where lime slurry was injected to neutralize sulfuric acid up to 20 feet deep. Another pilot-scale test was performed at a burial pit where in situ grouting was used as a means for remedial action for uranium mill tailing piles. Field tests of the system have been performed under controlled, nonhazardous conditions. The location for the SITE demonstration is undetermined.

#### Remediation Costs

No cost information is available.

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## Hydrolytic Terrestrial Dissipation

### Low-Level Toxaphene and Other Pesticides in Soil

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#### Technology Description

Dames & Moore developed its Hydrolytic Terrestrial Dissipation (HTD) process for use at the Chemairspray site in Palm Beach County, Florida. An estimated 11,500 cubic yards of surface soils at the site are contaminated with toxaphene — a chlorinated pesticide — and metal fungicides, primarily copper.

HTD involves excavating contaminated soils and comminuting (mixing and cutting) soils so that metal complexes and organic chemicals in the soil are uniformly distributed. During the mixing process, caustic addition raises the soil pH to 8.0 or greater, although slower reactions should still occur at lower pHs. Soil moisture levels are maintained during mixing to prevent adsorption and fugitive dust. Iron, copper, or aluminum can be introduced to catalyze the hydrolysis.

The prepared mixture is then distributed in a thin veneer (4 to 7 centimeters) over a soil bed and exposed to heat and ultraviolet light from the sun to facilitate dissipation. Since lighter weight toxaphene compounds are reported to be volatile, volatility will enhance dissipation. Toxaphene's volatility will increase as heavier compounds are dehalogenating to lower molecular weights. Ultraviolet light is also known to cause toxaphene dechlorination, so toxaphene gases in the atmosphere will slowly degrade to still lower molecular weights while liberating chlorine. Since lighter compounds have fewer chlorines in their molecular structure, only minor amounts of chlorine gas are emitted to the atmosphere. In fact, throughout the entire study, chlorine gas emission is estimated to be less than 0.25 grams per day over the study area.

Soils in the distribution bed are periodically sampled to evaluate any residual contamination. Also, monitoring of underlying ground water assures maintenance of environmental quality during HTD system operation. After treated soils meet established criteria, the land may be returned to agricultural production or other beneficial use. Since toxaphene is chlorinated camphene, dehalogenation reduces the insecticide to a naturally occurring compound. The treatment capacity of one staging unit is approximately 5,000 to 6,000 tons per year.

HTD takes advantage of the metal-catalyzed alkaline hydrolysis reactions to liberate chlorine ions that form various metal salts, depending on the characteristics of the contaminated media. Camphene ( $C_{10}H_{16}$ ) will ultimately be left to degrade to water and carbon oxides ( $CO_x$ ).

HTD has applications at sites where large quantities of soil are contaminated by small amounts of toxaphene or other pesticides. Depending on the pesticide, metal catalysts other than copper and iron could be effective. The process involves a hydrolysis reaction; however, flash points, vapor pressures, and other elements of physical chemistry can be used to enhance dissipation and should be considered when designing the remedial measure. Although it may have such application, this method was not developed for highly concentrated soil contaminants.

#### Technology Performance

This technology was accepted into the SITE Demonstration Program in the Spring 1991. The SITE demonstration will be carried out at the Chemairspray facility after the completion of treatability studies. A simulation tank has been constructed to evaluate rates of hydrolysis under

laboratory conditions. A quality control program has been instituted to validate laboratory results. A Quality Assurance Project Plan was prepared and is being reviewed by EPA.

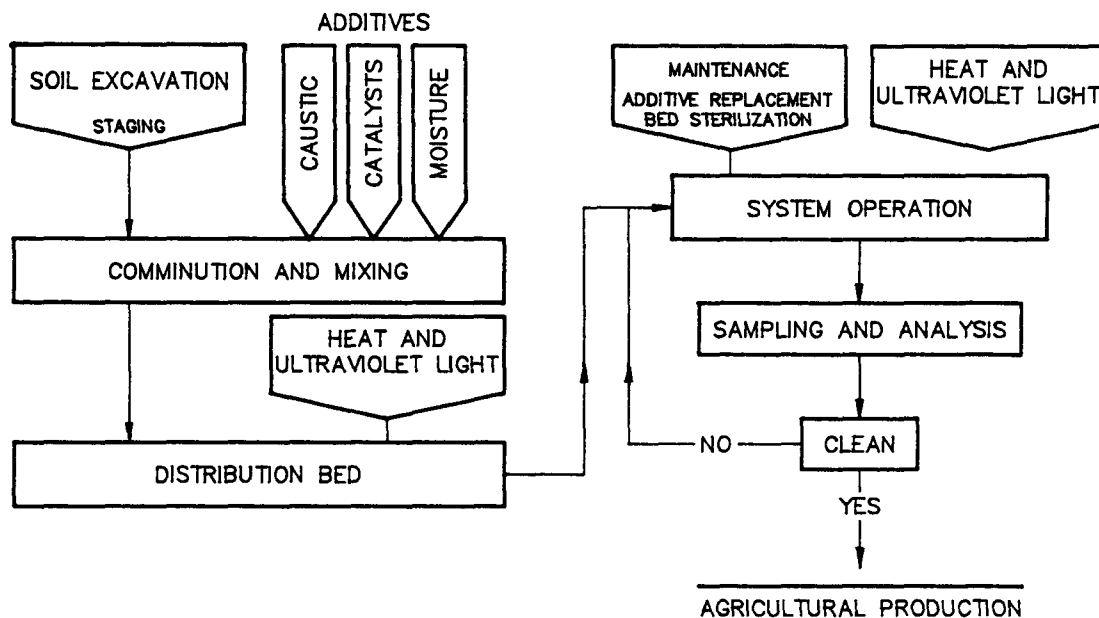
### Remediation Costs

No cost information is available.

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Hydrolytic terrestrial dissipation schematic



## **In Situ Vitrification**

### **Organics and Inorganics in Soil and Sludge**

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#### **Technology Description**

In situ vitrification (ISV) uses an electric current to melt soil or sludge at extremely high temperatures of 1,600°C to 2,000°C, thus destroying organic pollutants by pyrolysis. Inorganic pollutants are incorporated within the vitrified mass, which has glass properties. Water vapor and organic pyrolysis byproducts are captured in a hood, which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants.

The vitrification process begins by inserting large electrodes into contaminated zones containing sufficient soil to support the formation of a melt. An array (usually square) of four electrodes is placed to the desired treatment depth in the volume to be treated. Because soil typically has low electrical conductivity, flaked graphite and glass frit are placed on the soil surface between the electrodes to provide a starter path for electric current. The electric current passes through the electrodes and begins to melt soil at the surface. As power is applied, the melt continues to grow downward, at a rate of 1 to 2 inches per hour. Individual settings (each single placement of electrodes) may grow to encompass a total melt mass of 1,000 tons and a maximum width of 35 feet.

Single-setting depths as great as 25 feet are considered possible. Depths exceeding 19 feet have been achieved with the existing large-scale ISV equipment. Adjacent settings can be positioned to fuse to each other and to completely process the desired volume at a site. Stacked settings to reach deep contamination are also possible. The large-scale ISV system melts soil at a rate of 4 to 6 tons per hour. Because the void volume present in particulate materials (20 to 40 percent for typical soils) is removed during processing, a corresponding volume

reduction occurs. After cooling, a vitrified monolith results, with a silicate glass and micro-crystalline structure. This monolith possesses excellent structural and environmental properties.

The mobile ISV system is mounted on three semitrailers. Electric power is usually taken from a utility distribution system at transmission voltages of 12.5 or 13.8 kilovolts; power may also be generated on-site by a diesel generator. The electrical supply system has an isolated ground circuit to provide appropriate operational safety.

Air flow through the hood is controlled to maintain a negative pressure. An ample supply of air provides excess oxygen for combustion of any pyrolysis products and organic vapors from the treatment volume. Off-gases are treated by (1) quenching, (2) pH controlled scrubbing, (3) dewatering (mist elimination), (4) heating (for dewpoint control), (5) particulate filtration, and (6) activated carbon adsorption.

The ISV process can be used to destroy or remove organics and to immobilize inorganics in contaminated soils or sludges. In saturated soils or sludges, water is driven off at the 100°C isotherm moving in advance of the melt. Water removal increases energy consumption and associated costs. Also, sludges must contain a sufficient amount of glass-forming material (non-volatile, non-destructible solids) to produce a molten mass that will destroy or remove organic pollutants and immobilize inorganic pollutants. The ISV process is limited by (1) individual void volumes in excess of 150 cubic feet, (2) rubble exceeding 20 percent by weight, and (3) combustible organics in the soil or sludge exceeding 5 to 10 weight percent, depending on the heat value.

## **Technology Performance**

The ISV process has been operated at a large scale ten times, including two demonstrations on transuranic-contaminated (radioactive) sites: (1) at Geosafe's test site, and (2) at the Department of Energy's (DOE) Hanford Nuclear Reservation. It has also been used at EPA Superfund, private, and other DOE sites. More than 130 tests at various scales have been performed on a broad range of waste types in soils and sludges. The technology has been selected as a preferred remedy at 10 private, EPA Superfund, and DOE sites. The Parsons/ETM site in Grand Ledge, Michigan has been selected for the SITE demonstration. Geosafe is currently doing further technology testing before any field remediation work.

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## **In Situ Vitrification**

### **Organics, Inorganics, and Radionuclides in Soils**

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#### **Technology Description**

The in situ vitrification (ISV) process fixes fission products and immobilizes or destroys hazardous chemicals in soils at mixed hazardous waste sites. This technology can be applied to radionuclides, heavy metals, and hazardous organic-contaminated soil.

ISV is the conversion of contaminated soil into a durable glass and crystalline waste form through melting the soil by joule heating. Contaminants are destroyed by or immobilized in molten glass (melted soil). Soil is melted by electrical energy from electrodes that are placed in the ground. Off-gas from this process is treated by conventional off-gas treatment methods.

This technology has a number of benefits. Specifically, ISV may safely immobilize or destroy both radioactive and hazardous chemicals before they impact the ground water or other ecosystems. It is applicable to soils contaminated with fission products, transuranics, hazardous metals, and hazardous organics. It reduces the risk to the public by immobilizing or destroying radioactive and hazardous materials in the soil. Finally, in situ treatment poses a lower potential risk to workers than traditional treatments because contaminants are not brought to the surface. This technology, however, has not yet been demonstrated at depths beyond twenty feet.

The ISV technology can be applied to a wide range of soil types and contaminants. Melt depths of approximately 5 meters are considered the practical limit for most sites at this time. However, additional research is being conducted to ultimately achieve melt depths of up to 10 meters. There are no practical limits for inorganic contaminants; current processing systems

are designed to process up to 8 wt. percent organics based on heat loading considerations. High moisture soils can generally be processed, but saturated soils with free flowing ground water would require the use of methods to minimize ground-water recharge. With use of electrode feeding technology (vertically moveable electrodes), inclusions such as scrap metals and buried piping can be processed without concern of electrical short circuits.

#### **Technology Performance**

Recent field-scale demonstrations have been conducted at the U.S. Department of Energy's (DOE) Hanford Site and Oak Ridge National Laboratory. During a large-scale demonstration at the Hanford Site, a liquid waste disposal crib constructed of wooden timber was vitrified producing a monolith of over 800 tons in size. Contamination in soils in and below the crib contained heavy metals, such as lead and chromium, and radionuclides, including an estimated 900 mCi of strontium-90 and 150 mCi of cesium-137. The demonstration was conducted under CERCLA guidelines in 1990. Coring of the block was completed in 1991, data analysis is being finalized, and a comprehensive report will be completed during FY 1992. Key results indicated the following:

- The ISV process maintained an 87 percent on-line operating efficiency during the test;
- The off-gas treatment system easily accommodated the additional off-gas and heat loads from the thermal decomposition of the crib's wooden timbers;
- Analyses of cores taken from the monolith revealed a homogeneous composition due to the convective mixing currents that occur in the melt;



- The resulting glass and crystalline product easily passed TCLP criteria;
- Melt depth was limited to 4.3 meters (the bottom of the crib) and was hindered by a cobble layer beneath the crib.

A second ISV field demonstration was conducted in May 1991 on a one-quarter-scale liquid waste disposal trench containing 10 mCi of cesium-137. The trench was designed to simulate the liquid waste disposal trenches at Oak Ridge National Laboratory, many of which contain thousands of curies of cesium-137 and strontium-90. The test was conducted over a five-day period and achieved a melt depth of about 2.75 meters, exceeding expectations for the pilot-scale system. Post-test analyses are underway, and comprehensive results are to be reported late in 1992. Key results included the following:

- Approximately 97.3 wt. percent of cesium was retained in the melt. A particulate filter system installed on the off-gas line was used to effectively prevent the balance of cesium that was volatilized during the vitrification process (2.7 wt. percent) from reaching the off-gas treatment trailer;

- Surrounding soils were determined to be free of contamination by the cesium indicating that no outward migration occurred;
- Post-test evaluations of the vitrified product revealed that the cesium partitioned in the glass phases of the block rather than in the crystalline phases or at phase boundaries.

### **Remediation Costs**

Approximately \$300 to \$450 per ton of soil exclusive of costs for mobilization and demobilization of the process equipment.

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## **Pneumatic Fracturing Extraction and Catalytic Oxidation VOCs and Semi-VOCs in Soil and Rock**

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### **Technology Description**

An integrated treatment system incorporating Pneumatic Fracturing Extraction (PFE) and Catalytic Oxidation has been jointly developed by Accutech Remedial Systems Inc., and the Hazardous Substance Management Research Center located at the New Jersey Institute of Technology in Newark, New Jersey. The system provides a cost-effective accelerated remedial approach to sites with Dense Non-Aqueous Phase Liquid (DNAPL) contaminated aquifers. The patented PFE process has been demonstrated both in the laboratory and in the field to establish a uniform subsurface airflow within low permeability formations such as clay and fractured rock. The PFE process coupled with an in situ thermal injection process is designed to recover residual contamination entrapped in the vadose zone. A ground-water recovery system is first implemented to suppress the water table below the zone of highest contamination. Recovered ground water is treated by an aeration process. DNAPL contaminants removed from the ground water are combined with the PFE recovery process stream. The combined DNAPL vapor stream is fed into a catalytic oxidation unit for destruction. The oxidation unit contains a catalyst which has been shown to resist process deactivation. Heat from the catalytic/oxidation unit is utilized in the in situ thermal injection component of the

treatment system. The treatment system also has the ability to utilize activated carbon treatment technology when contaminant concentrations decrease to levels where catalytic technology is no longer cost-effective.

The integrated treatment system is cost-effective for treating soils and rock where conventional in situ technologies are limited in their effectiveness because of the presence of low permeability geologic formations. Halogenated and non-halogenated volatile and semivolatile organic compounds can be remediated by this system.

### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in December 1990. The demonstration was conducted late in 1991 at a New Jersey Department of Environmental Protection and Energy Environmental Cleanup Responsibility Act (ECRA) site in South Plainfield, New Jersey, where trichloroethene (TCE) was removed from a fractured shale aquifer.

The demonstration also included the development of engineering cost data for catalytic oxidation and carbon adsorption technologies by alternating between the two treatment methods.

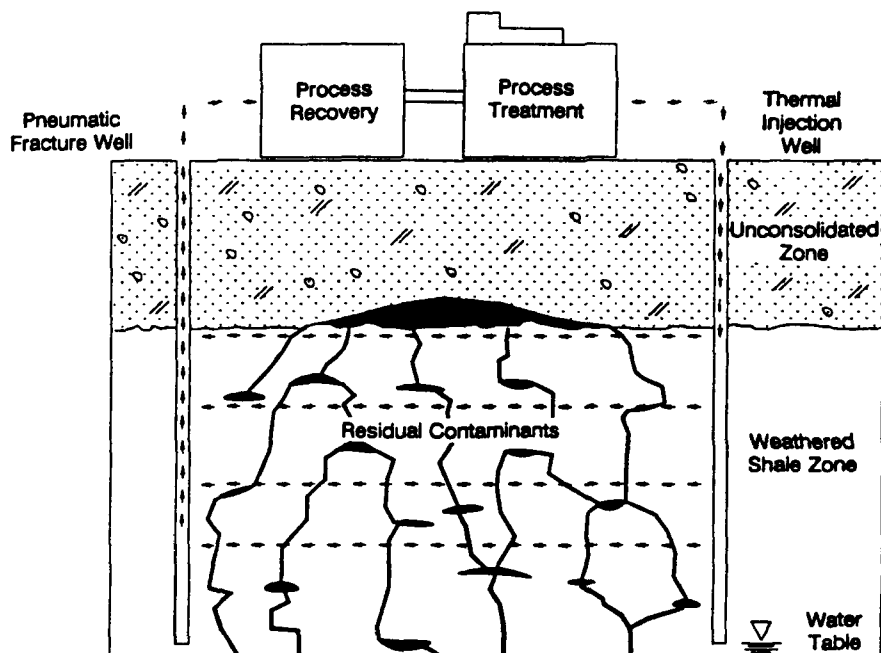
### **Remediation Costs**

No cost information is available.

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Pneumatic Fracturing Extraction  
and Catalytic Oxidation



## Precipitation, Microfiltration, and Sludge Dewatering Pesticides, Oil, and Grease in Sludge and Leachable Soil

### Technology Description

In the first step of this process, heavy metals are chemically precipitated. The precipitates along with all particles down to 0.2 to 0.1 micron, are filtered through a unique fabric crossflow microfilter (EXXFLOW). The concentrate stream is then dewatered in an automatic tubular filter press of the same fabric material (EXXPRESS).

EXXFLOW microfilter modules are fabricated from a proprietary woven polyester array of tubes. Wastes are pumped into the tubes from a dynamic membrane, which produces a high quality filtrate removing all particle sizes greater than 0.2 - 0.1 micron. The membrane is continually cleaned by the flow velocity, thereby minimizing production declines and cleaning frequencies.

Metals are removed via precipitation by adjusting the pH in the EXXFLOW feed tank. The metal hydroxides or oxides form the dynamic membrane with any other suspended solids. The concentrate stream will contain up to 5 percent solids for discharge to the EXXPRESS system. The EXXFLOW concentrate stream enters the EXXPRESS modules with the discharge valve closed. A semi-dry cake, up to 1/4 inch thick, is formed on the inside of the tubular cloth. When the discharge valve is opened, rollers on the outside of the tube move to form a venturi within the tube. The venturi creates an area of high velocity within the tubes, which aggressively cleans the cloth and discharges the cake in chip form onto a wedge wire screen. The discharge water is recycled back to the feed tank. The EXXPRESS filter cakes are typically 40 to 60 percent solids by weight.

Other constituent removals are possible using seeded slurry methods in EXXFLOW. Hard-

ness can be removed by using lime. Oil and grease can be removed by adding adsorbents. Non-volatile organics and solvents can be removed using seeded, powdered activated carbon or powdered ion exchange adsorbents.

In cases where the solids in the raw feed are extremely high, EXXPRESS can be used first, with EXXFLOW acting as a final polish for the product water.

The EXXFLOW/EXXPRESS demonstration unit is transportable and is skid-mounted. The unit is designed to process approximately 30 pounds of solids per hour and 10 gallons per minute of wastewater.

This technology is applicable to water containing heavy metals, pesticides, oil and grease, bacteria, suspended solids, and constituents that can be precipitated into particle sizes greater than 0.1 micron. The system can handle waste streams containing up to 5 percent solids and produce a semi-dry cake of 40 to 60 percent weight per weight. Non-volatile organics and solvents can also be removed from the water by adding powdered adsorbents.

Soils and sludge can be decontaminated through acid leaching of the metals, followed by precipitation and microfiltration. Lime sludges from municipal, industrial, and power plant clarifiers can also be treated by using this process.

### Technology Performance

This technology was accepted into the SITE Demonstration Program in 1989. Bench-scale tests were conducted in 1990. The first EPA application was acid mine drainage at the Iron

Mountain Mine Superfund site in Redding, California, in late 1991.

Since 1988, this technology has been applied to over 35 sites worldwide. System capacities range from 1 gallon per minute to over 2 million gallons per day. Applications include (1) industrial laundries, (2) circuit board shops, (3) ceramics, (4) agricultural chemicals, (5) oil produced water, (6) oil field waste, (7) scrubber waste, (8) municipal waste, (9) water purification, (10) water softening, (11) clarifier sludge dewatering, and (12) wine and juice filtration.

#### **Remediation Costs**

No cost information is available.

#### **Contacts**

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3065 Sunnyside, #101  
Fresno, CA 93727  
209/291-8144



## **Rotary Air Stripping**

### **Volatile Contaminants in Ground water**

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#### **Technology Description**

A rotary air stripper is a vapor and liquid contactor which uses centrifugal force to push contaminated water through packing material while air is pushed counter current to the flow of water. The centrifugal force results in a high mass transfer rate of the contaminant from the water to the air. The main advantage of this rotary air stripper is the reduction of the height of the stripping equipment. Large, tall towers are inherent in conventional packed column air stripping.

#### **Technology Performance**

In the first tests with a rotary air stripper conducted at the Traverse City Coast Guard Station, a 100 gpm rotary air stripper showed removal of the contaminant as a function of the liquid to gas ratio and the speed (rpm) of the spinning rotor. The data showed that the removal efficiency increased with an increase in the gas-to-liquid ratio up to a value of about 30 (vol/vol). Above this value, minimal increases in removal efficiencies were realized with increased gas-to-liquid ratios. A similar phenomenon was observed when assessing the effect of the rotor speed on the removal efficiency. Increasing the rotation above approximately 600 rpm produced minimal changes in the removal efficiency. In all the tests, high removal efficiencies (greater than 99 percent) were achieved with the highly volatile contaminants, while relatively low removal efficiencies were observed for the less volatile contaminants. In these tests, only one size and type of packed rotor was used, and only influent and effluent data could be taken.

In the second tests, conducted at Eglin AFB, three different sizes of rotors and two different

types of packing materials were used, along with an internal sampling mechanism. Using the different packed rotors, data was obtained to develop and compare equations for predicting the mass transfer pressure drops, and power consumption of the 50 gpm rotary air stripper. The equations can be used to design the size, rotating speed, air-to-water ratios, and energy necessary for a rotary air stripper to meet site-specific performance requirements.

A final report on the Eglin studies is in publication. The document outlines the work done to remove BETX compounds from ground water. A cost spreadsheet was developed and is available through the contact below.

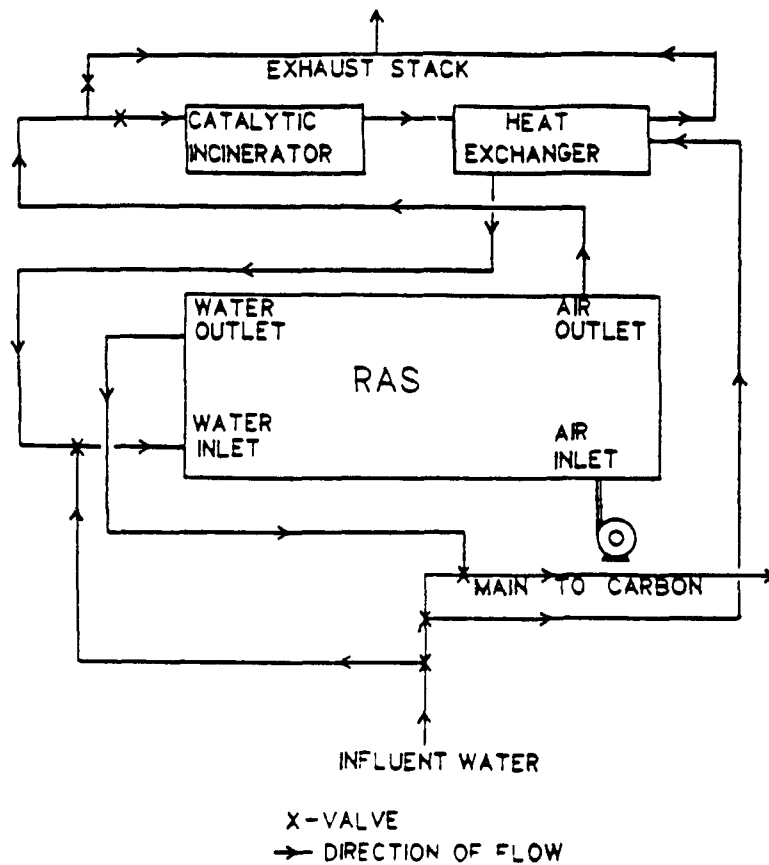
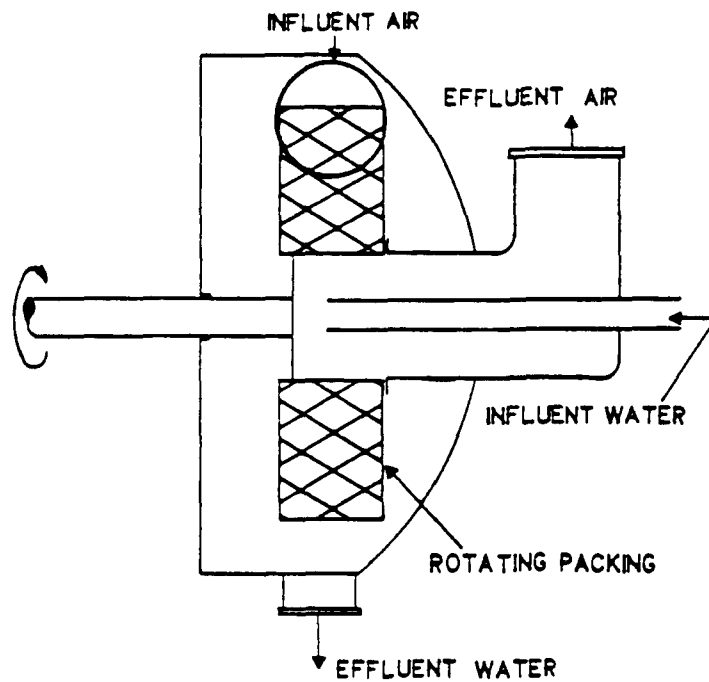
The only limitation noted was that plugging occurred due to mineral deposits in the rotors at one site where the water has a very high iron content (approximately 9 ppm).

#### **General Site Information**

Field tests have been conducted at Eglin AFB and at the U.S. Coast Guard Station at Traverse City, Michigan.

#### **Contact**

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Rotary Air Stripping Process



## **Thermal Gas Phase Reduction Process**

### **PCBs, PAHs, Chlorophenols, and Pesticides in Soil, Sludge, Liquids, and Gases**

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#### **Technology Description**

This patented process is based on the gas-phase, thermo-chemical reaction of hydrogen with organic and chlorinated organic compounds at elevated temperatures. At 850°C or higher, hydrogen reacts with organic compounds in a process known as reduction to produce smaller, lighter hydrocarbons. This reaction is enhanced by the presence of water, which can also act as a reducing agent. Because hydrogen is used to produce a reducing atmosphere devoid of free oxygen, the possibility of dioxin or furan formation is eliminated.

The thermo-chemical reaction takes place within a specially designed reactor. In the process, a mixture of preheated waste and hydrogen is injected through nozzles mounted tangentially near the top of the reactor. The mixture swirls around a central ceramic tube past glo-bar heaters. By the time the mixture passes through the ports at the bottom of the ceramic tube, it has been heated to 850°C. Particulate matter up to 5 millimeters in diameter not entrained in the gas stream will impact the hot refractory walls of the reactor. Organic matter associated with the particulate is volatilized, and the particulate exits out of the reactor bottom to a quench tank, while finer particulate entrained in the gas stream flows up the ceramic tube into an exit elbow and through a retention zone. The reduction reaction takes place from the bottom of the ceramic tube onwards, and takes less than one second to complete. Gases enter a scrubber where hydrogen chloride fine particulates are removed. The gases that exit the scrubber consist only of excess hydrogen, methane, and a small amount of water vapor. Approximately 95 percent of this gas is recirculated back into the reactor. The remaining 5 percent is fed to

a boiler where it is used as supplementary fuel to preheat the waste.

Because this process is not incineration, the reactor does not require a large volume for the addition of combustion air. The small reactor size and the capability to recirculate gases from the reaction make the process equipment small enough to be mobile.

In addition, the process includes a sophisticated on-line mass spectrometer unit as a part of the control system. As the unit is capable of measuring many organic chemicals on a continuous basis, increases in chlorobenzene or benzene concentrations (signalling a decrease in destruction efficiency) halt the input of waste and alert the operator.

The technology is suitable for many types of waste including polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), chlorophenols, pesticides, landfill leachates, and lagoon bottoms. The system can handle most types of waste media, including soils, sludges, liquids, and gases. Even those wastes with a high water content are easily handled by the technology. The maximum concentration level is 30 percent sediments and 10 percent chlorine.

In the case of chlorinated organic compounds, such as PCBs, the products of the reaction include chloride, hydrogen, methane, and ethylene. Other non-chlorinated hazardous contaminants, such as PAHs, are also reduced to smaller, lighter hydrocarbons, primarily methane and ethylene.



## **Technology Performance**

This technology was accepted into the SITE Demonstration Program in July 1991. A demonstration-scale reactor, two meters in diameter and three meters tall, capable of handling 7 tons per day, has been used for processing PAH- and PCB-contaminated harbor sediments in Hamilton, Ontario. Bench-scale testing with trichlorobenzene has shown that the reduction reaction can achieve 99.9999 percent destruction efficiency or better. A possible location for holding the SITE demonstration has been identified.

## **Remediation Costs**

No cost information is available.

## **Contacts**

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143 Dennis Street  
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Canada N0 B2 K0  
519/856-9591



## Ultrafiltration

### Toxic Metals in Ground water

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#### Technology Description

This combination chemical-ultrafiltration treatment process is intended for use on toxic metals in ground water. Ultrafiltration has thus far been applied exclusively to the removal of colloidal solids and fairly large molecules. This technology may potentially be used to separate toxic heavy metals such as cadmium, chromium, lead, mercury, selenium, silver and barium (as an in situ formed precipitate) from ground water generated at Superfund sites. Other inorganic and organic materials present as suspended and colloidal solids may also be removed.

Ultrafiltration can be applied in combination with chemical treatment to selectively remove dissolved metal ions from dilute aqueous solutions. A high molecular weight chelating agent is added to the incoming waste solutions to form macromolecular complexes. The metal ions can then be easily removed.

Usually, each chelating polymer is marked for one metal or for a group of similar cations. Once the polymer is added, the solution is processed through an ultrafiltration membrane system that collects the macromolecular complexes (retentate) on the membrane, but allows uncomplexed ions such as sodium, potassium, calcium, chloride, sulfate, and nitrate, to pass through as filtered water (permeate). The filtered water can be recycled or discharged depending upon the metal removal requirements. A removal efficiency approaching 100 percent can be achieved for metal ions in ground water.

The retentate, which constitutes about 5 to 20 percent of the feed volume, contains the separated heavy metal ions and must be treated further. The retentate is either solidified to prevent the release of toxic metals back to the environment or recycled through the treatment process for further volume reduction.

Because many simple and non-toxic ions are allowed to pass through the membrane as permeate, they are not concentrated together with the metal ions. The retentate will have a smaller volume and the solidified product will be more resistant to leaching, due to its smaller salt content and the presence of chemicals that retard the migration of toxic metals.

#### Technology Performance

Results of bench-scale tests showed the following removal rates: cadmium and mercury, up to 99 percent; lead, 90 percent; and arsenic, 10 to 35 percent. Arsenic is an anionic species, and is not as effectively removed as the other metals. Separation of non-arsenic metals was found to be more efficient in alkaline conditions. This research also indicated that ultrafiltration, unlike conventional precipitation technologies, does not require the production of large particles and, thus, may be more applicable to feed streams with high variability in metals concentration.

## **Contacts**

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**Chalk River, Ontario KOJ IJO**  
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**613/584-3311**



## **Ultraviolet Radiation and Oxidation**

### **Halogenated Hydrocarbons, VOCs, Pesticides, and PCBS in Ground water**

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#### **Technology Description**

This ultraviolet (UV) radiation and oxidation process uses UV radiation, ozone ( $O_3$ ), and hydrogen peroxide ( $H_2O_2$ ) to destroy toxic organic compounds, particularly chlorinated hydrocarbons, in water. The process oxidizes compounds that are toxic or refractory (resistant to biological oxidation) in concentrations of parts per million or parts per billion.

The system consists of a treatment tank module, an air compressor and ozone generator module, and a hydrogen peroxide feed system. It is skid-mounted and portable, and permits on-site treatment of a wide variety of liquid wastes, such as industrial wastewaters, ground waters, and leachate. The treatment tank size is determined from the expected wastewater flow rate and the necessary hydraulic retention time to treat the contaminated water. The approximate UV intensity, and ozone and hydrogen peroxide doses, are determined from pilot-scale studies.

Influent to the treatment tank is simultaneously exposed to UV radiation, ozone, and hydrogen peroxide to oxidize the organic compounds. Off-gas from the treatment tank passes through an ozone destruction (Decompozon) unit, which reduces ozone levels before air venting. The Decompozon unit also destroys volatile organic compounds (VOC) stripped off in the treatment tank. Effluent from the treatment tank is tested and analyzed before disposal.

Contaminated ground water, industrial wastewaters, and leachates containing halogenated solvents, phenol, pentachlorophenol, pesticides, polychlorinated biphenyls (PCB), and other organic compounds are suitable for this treatment process.

#### **Technology Performance**

A field-scale demonstration was completed in March 1989 at a hazardous waste site in San Jose, California. The test program was designed to evaluate the performance of the Ultrox system at several combinations of five operating parameters: (1) influent pH, (2) retention time, (3) ozone dose, (4) hydrogen peroxide dose, and (5) UV radiation intensity. The Technology Evaluation Report was published in January 1990 (EPA/540/5-89/012). The Applications Analysis Report was published in September 1990 (EPA/540/A5-89/012).

Contaminated ground water treated by the Ultrox system met regulatory standards at the appropriate parameter levels. Out of 44 VOCs in the wastewater, three were chosen to be used as indicator parameters. They are trichloroethylene (TCE), 1,1 dichloroethane (1,1-DCA), and 1,1,1 trichloroethane (1,1,1-TCA), all relatively refractory to conventional oxidation.

Removal efficiencies for TCE were about 99 percent. Removal efficiencies for 1,1-DCA and 1,1,1-TCA were about 58 percent and 85 percent, respectively. Removal efficiencies for total VOCs were about 90 percent.

For some compounds, removal from the water phase resulted from both chemical oxidation and stripping. Stripping accounted for 12 to 75 percent of the total removal for 1,1,1-TCA, and 5 to 44 percent for 1,1-DCA. Stripping was less than 10 percent for TCE and vinyl chloride, and was negligible for other VOCs present.

The Decompozon unit reduced ozone to less than 0.1 ppm Occupational Safety and Health Act (OSHA) standards, with efficiencies greater than 99.99 percent. VOCs present in the air within the treatment system were not detected

after passing through the Decompozon unit. There were no harmful air emissions to the atmosphere from the Ultrox system.

Very low total organic carbon (TOC) removal was found, implying partial oxidation of organics without complete conversion to carbon dioxide and water.

The technology is fully commercial, with over 20 commercial systems installed. Flow rates ranging from 5.0 gallons per minute to 1,050 gallons per minute are presently being used in various industries and site clean-up activities, including aerospace, Department of Energy (DOE), petroleum, pharmaceutical, automotive, woodtreating and municipal.

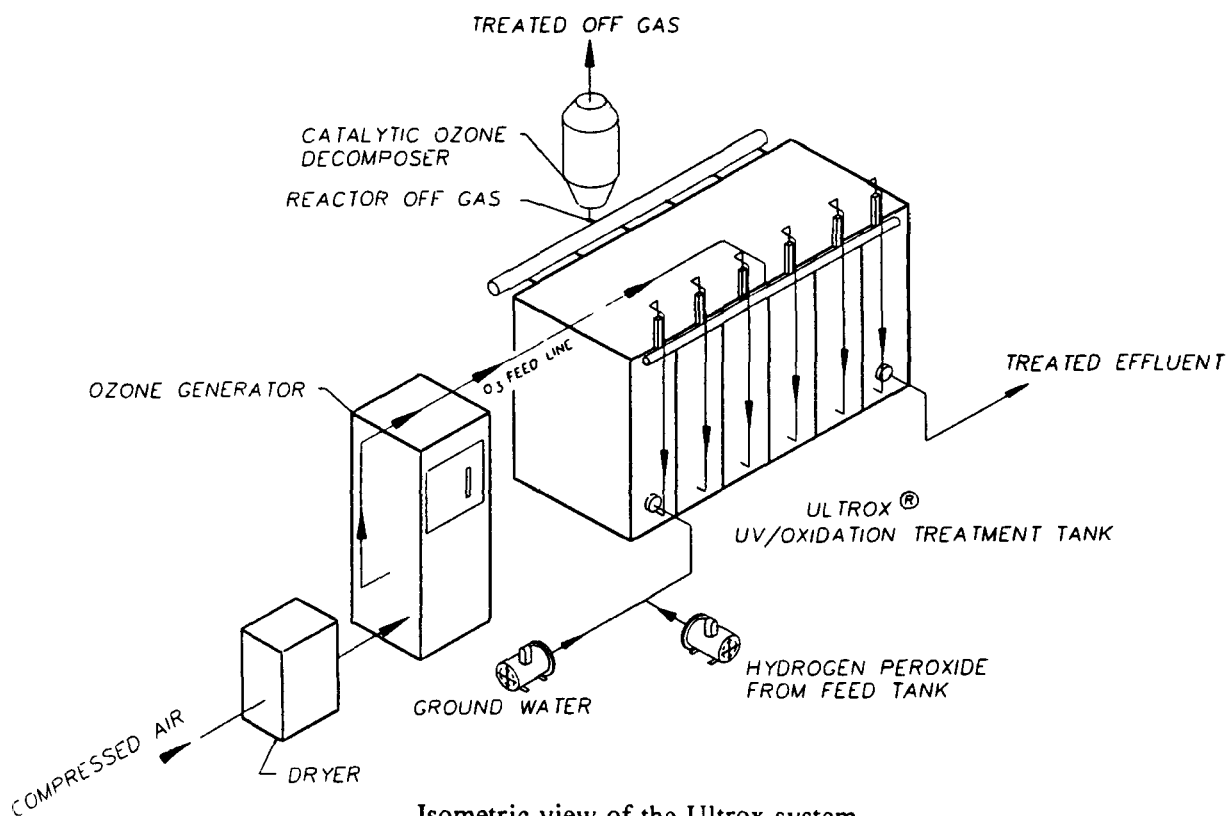
## Remediation Costs

No cost information is available.

## Contacts

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Ultrox International  
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Santa Ana, CA 92704  
714/545-5557



Isometric view of the Ultrox system



## Ultraviolet Radiation, Hydrogen Peroxide, and Ozone Trichloroethylene in Ground Water

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### Technology Description

This oxidation process uses ozone, ultraviolet radiation, and hydrogen peroxide for the treatment of ground water contaminated with trichloroethylene (TCE).

### Technology Performance

Results from the full-scale, advanced oxidation process tested at the DOE Kansas City plant were mostly inconclusive:

- The plant is effective in the destruction of individual volatile organic compounds but seems to reach a plateau for gross parameters such as total organic carbon and total chlorinated hydrocarbons;
- The plant has been out of service for maintenance and repair approximately 30 percent of the time;
- The flow rate has averaged approximately 15 percent of the design flow rate, so the determination of costs has been inconclusive; and

- An evaluation of the true plant capacity indicates that it can accommodate twice the rated flow rate.

### Remediation Costs

Actual costs are not available; however, the costs are competitive with other processes.

### General Site Information

A full-scale, advanced oxidation process was tested at the DOE Kansas City Plant.

### Contact

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P.O. Box 2008  
Oak Ridge, Tennessee 37831-6317  
615/574-8581



## **Wetlands-Based Treatment**

### **Metals in Influent Waters**

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#### **Technology Description**

The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in a man-made wetland ecosystem to accumulate and remove metals from influent waters. The treatment system incorporates principal ecosystem components found in wetlands, including organic soils, microbial fauna, algae, and vascular plants.

Influent waters, which contain high metal concentrations and have a low pH, flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed by filtration, ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction. In filtration, metal flocculates and metals that are adsorbed onto fine sediment particles settle in quiescent ponds, or are filtered out as the water percolates through the soil or the plant canopy. Ion exchange occurs as metals in the water come into contact with humic or other organic substances in the soil medium. Oxidation and reduction reactions that occur in the aerobic and anaerobic zones, respectively, play a major role in removing metals as hydroxides and sulfides.

The wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high metals concentrations and are acidic in nature. Wetlands treatment has been applied with some success to wastewater in the eastern regions of the United States. The process may have to be adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.

#### **Technology Performance**

As a result of the success of this technology in the Emerging Technology Program, it has been selected for the Demonstration Program.

The final year of the project under the Emerging Technology Program was 1991. Results of a study of drainage from the Big Five Tunnel near Idaho Springs, Colorado, have shown that by optimizing design parameters, removal efficiency of heavy metals from the discharge can approach the removal efficiency of chemical precipitation treatment plants.

One of the final goals of this project was the development of a manual that discusses design and operating criteria for construction of a full-scale wetland for treating acid mine discharges.

The Demonstration Program will evaluate the effectiveness of a full-scale wetland. Construction of a full-scale wetland is the proposed remedial action for the Burleigh Tunnel near Silver Plume, Colorado. The Burleigh Tunnel is part of the Clear Creek/Central City Superfund Site in Colorado.

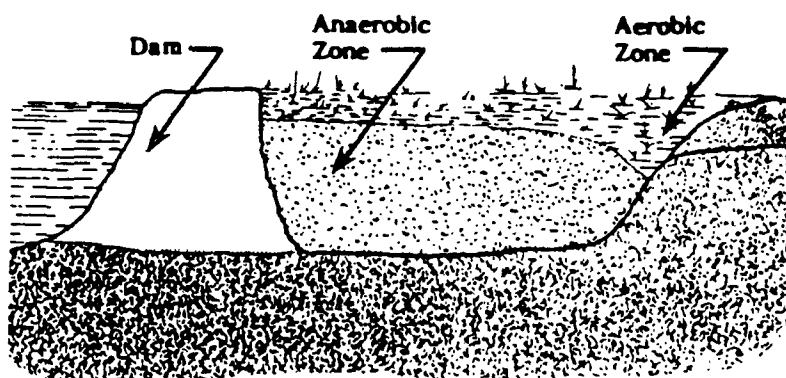
#### **Remediation Costs**

No cost information is available.

## Contacts

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Typical wetland ecosystem



## ***Appendix A***

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# **Incineration and Solidification Demonstrations**

## **Circulating Bed Combustor**

### **Halogenated and Non-Halogenated Organic Compounds and PCBs in Soil, Sludge, and Liquids**

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#### **Technology Description**

The Circulating Bed Combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone for the efficient destruction of toxic hydrocarbons. The commercial-size combustion chamber (36 inches in diameter) can treat up to 150 tons of contaminated soil daily, depending on the heating value of the feed material.

The CBC operates at fairly low temperatures 1450 to 1600°F for this class of technology, thus reducing operating costs and potential emissions such as nitrogen oxides (NO<sub>x</sub>) and carbon monoxide. Auxiliary fuel can be natural gas, fuel oil, or diesel. No auxiliary fuel is needed for waste streams having a net heating value greater than 2,900 British thermal units per pound. The CBC's high turbulence produces a uniform temperature around the combustion chamber and hot cyclone. It also promotes the complete mixing of the waste material during combustion. The effective mixing and relatively low combustion temperature also reduce emissions of carbon monoxide and nitrogen oxides. Hot gases produced during combustion pass through a convective gas cooler and baghouse before being released to the atmosphere.

Waste material and limestone are fed into the combustion chamber along with the recirculating bed material from the hot cyclone. The limestone neutralizes acid gases. The treated ash is transported out of the system by an ash conveyor for proper disposal.

The CBC process may be applied to liquids, slurries, solids, and sludges contaminated with corrosives, cyanides, dioxins/furans, inorganics,

metals, organics, oxidizers, pesticides, polychlorinated biphenyls (PCB), phenols, and volatiles.

Industrial wastes from refineries, chemical plants, manufacturing site cleanups, and contaminated military sites are amenable to treatment by the CBC process. The CBC is permitted by EPA, under the Toxic Substance Control Act (TSCA), to burn PCBs in all ten EPA regions, having demonstrated a 99.9999 percent destruction removal efficiency (DRE).

Waste feed for the CBC must be sized to less than 1 inch. Metals in the waste do not inhibit performance and become less leachable after incineration. Treated residual ash can be replaced on-site or stabilized for landfill disposal if metals exceed regulatory limits.

#### **Technology Performance**

The technology was accepted into the SITE Demonstration Program in March 1989. Ogden Environmental Services (OES) conducted a treatability study and demonstration on wastes obtained from a Superfund site in California (McColl) under the guidance of the program, EPA Region 9, and the California Department of Health Services. The pilot-scale demonstration was conducted by using the 16-inch-diameter CBC at Ogden's Research Facility in San Diego, California.

The EPA SITE program concluded that the test successfully achieved the desired goals, as follows:

- Obtained DRE values of 99.99 percent or greater for principal organic hazardous

constituents (POHC) and minimized the formation of products of incomplete combustion(PIC).

- Met the OES Research Facility permit conditions and the California South Coast Basin emission standards.
- Controlled sulfur oxide emissions by adding limestone, and determined that the residual materials (fly ash and bed ash) were nonhazardous. No significant levels of hazardous organic compounds left the system in the stack gas or remained in the bed and fly ash material. The CBC was able to minimize emissions of sulfur oxide, nitrogen oxide, and particulates. Other regulated pollutants were controlled to well below permit levels.

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## **Contacts**

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513/569-7844

## **Infrared Thermal Destruction Organics in Soil and Sediment**

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### **Technology Description**

The infrared thermal destruction technology is a mobile thermal processing system that uses electrically powered silicon carbide rods to heat organic wastes to combustion temperatures. Any remaining combustibles are incinerated in an afterburner. One configuration for this mobile system consists of four components: (1) an electric-powered infrared primary chamber, (2) a gas-fired secondary combustion chamber, (3) an emissions control system, and (4) a control center.

Waste is fed into the primary chamber and exposed to infrared radiant heat (up to 1,850 degrees Fahrenheit) provided by silicon carbide rods above the belt. A blower delivers air to selected locations along the belt to control the oxidation rate of the waste feed. The ash material in the primary chamber is quenched by using scrubber water effluent. The ash is then conveyed to the ash hopper, where it is removed to a holding area and analyzed for organic contaminants, such as polychlorinated biphenyl (PCB) content.

Volatile gases from the primary chamber flow into the secondary chamber, which uses higher temperatures, greater residence time, turbulence, and supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system. In the emissions control system, the particulates are removed in a venturi scrubber. Acid vapor is neutralized in a packed tower scrubber. An induced draft blower draws the cleaned gases from the scrubber into the free-standing exhaust stack. The scrubber liquid effluent flows into a clarifier, where scrubber sludge settles out for disposal. The liquid then flows through an

activated carbon filter for reuse or to a publicly owned treatment works (POTW) for disposal.

This technology is suitable for soils or sediments with organic contaminants. Liquid organic wastes can be treated after mixing with sand or soil. Optimal waste characteristics are as follows:

- Particle size, 5 microns to 2 inches
- Moisture content, up to 50 percent by weight
- Density, 30 to 130 pounds per cubic foot
- Heating value, up to 10,000 British thermal units per pound
- Chlorine content, up to 5 percent by weight
- Sulfur content, up to 5 percent by weight
- Phosphorus, 0 to 300 parts per million (ppm)
- pH, 5 to 9
- Alkali metals, up to 1 percent by weight

### **Technology Performance**

EPA conducted two evaluations of the infrared system. An evaluation of a full-scale unit was conducted during August 1987, at the Peak Oil site in Tampa, Florida. The system treated nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. A second pilot-scale demonstration took place at the Rose Township/Demodé Road Superfund site in Michigan, during November 1987. Organics, PCBs, and metals in soil were the target waste compounds to be immobilized. In addition, the technology has been used to remediate PCB contamination at the Florida Steel Corporation and the LaSalle Electric Superfund sites.

The results from the two SITE demonstrations are summarized below.

- PCBs were reduced to less than 1 ppm in the ash, with a destruction removal efficiency (DRE) for air emissions greater than 99.99 percent (based on detection limits).
- In the pilot-scale demonstration, the Resource Conservation and Recovery Act (RCRA) standard for particulate emissions (180 milligrams per dry standard cubic meter) was achieved. In the full-scale demonstration, however, this standard was not met in all runs because of scrubber inefficiencies.
- Lead was not immobilized; however, it remained in the ash, and significant amounts were not transferred to the scrubber water or emitted to the atmosphere.
- The pilot testing demonstrated satisfactory performance with high feed rate and reduced power consumption when fuel oil was added to the waste feed and the primary chamber temperature was reduced.

Results from the two demonstrations, plus eight other case studies, indicate the process is capable of meeting both RCRA and TSCA DRE requirements for air emissions and particulate emissions. Restrictions in chloride levels in the feed waste may be necessary. PCB remediation has consistently met the TSCA guidance level of 2 ppm in ash.

### **Remediation Costs**

Economic analysis suggests an overall waste remediation cost up to \$800 per ton.

### **Contacts**

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Richard McAllister  
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## **PYRETRON® Thermal Destruction Organics in Soil, Sludge, and Solid Waste**

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### **Technology Description**

The PYRETRON® thermal destruction technology provides an integrated combustion system responsible for controlling the heat input into an incineration process by using the PYRETRON® oxygen-air-fuel burners and the dynamic control of the level of excess oxygen available for oxidation of hazardous waste. The PYRETRON® combustor uses an advanced combustion concept that relies on a new technique for mixing auxiliary fuel, oxygen, and air in order to (1) provide the flame envelope with enhanced stability, luminosity, and flame core temperature and (2) provide a reduction in the combustion volume per million British thermal units (Btu) of heat released.

The combustion system operation is computer controlled to automatically adjust the temperatures of the primary and secondary combustion chambers and the amount of excess oxygen being supplied to the combustion process. The system has been designed to dynamically adjust the amount of excess oxygen in response to sudden changes in the rate of volatilization of contaminants from the waste.

The burner system can be fitted onto any conventional incineration unit and used for the burning of liquids, solids, and sludges. Solids and sludges can also be co-incinerated when the burner is used in conjunction with a rotary kiln or similar equipment.

High and low Btu solid wastes contaminated with rapidly volatilized hazardous organics are suitable for the PYRETRON® technology. In general, the technology is applicable to any waste that can be incinerated. The technology is not suitable for processing aqueous wastes,

Resource Conservation and Recovery Act (RCRA) heavy metal wastes, or inorganic wastes.

### **Technology Performance**

A demonstration project was conducted at EPA's Combustion Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund site in California and 60 percent decanter tank tar sludge from coking operations (RCRA listed waste K087). The demonstration began in November 1987 and was completed at the end of January 1988.

Both the Technology Evaluation Report (EPA/540/5-89/008) and Applications Analysis Report (EPA/540/A5-89/008) have been published.

Six polycyclic aromatic hydrocarbons were selected as the principal organic hazardous constituents (POHC) for the test program — naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene.

The PYRETRON® technology achieved greater than 99.99 percent destruction and removal efficiencies (DRE) of all POHCs measured in all test runs performed. Other advantages are listed below:

- The PYRETRON® technology with oxygen enhancement achieved double the waste throughput possible with conventional incineration.
- All particulate emission levels in the scrubber system discharge were significantly below the hazardous waste incinerator

performance standard of 180 milligrams per dry standard cubic meter at 7 percent oxygen.

- Solid residues were contaminant-free.
- There were no significant differences in transient carbon monoxide level emissions between air-only incineration and PYRETRON® oxygen-enhanced operation with doubled throughput rate.
- Costs savings can be achieved in many situations.

The field evaluations conducted under the SITE Demonstration Program yielded the following conclusions:

- The PYRETRON® burner system is a viable technology for treating Superfund wastes.
- The system is capable of doubling the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values.
- In situations where particulate carryover causes operational problems, the PYRETRON® system may increase reliability.
- The technology can be an economical addition to an incinerator when operating and fuel costs are high and oxygen costs are relatively low.

## Contacts

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## **Chemfix Solidification/Stabilization Process**

### **Solid Waste in Soil and Sludge**

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#### **Technology Description**

This solidification and stabilization process is an inorganic system in which soluble silicates and silicate setting agents react with polyvalent metal ions and other waste components, to produce a chemically and physically stable solid material. The treated waste matrix displays good stability, a high melting point, and a friable texture. The treated matrix may be similar to soil, depending upon the water content of the feed waste.

The feed waste is first blended in the reaction vessel with dry alumina, calcium, and silica based reagents that are dispersed and dissolved throughout the aqueous phase. The reagents react with polyvalent ions in the waste and form inorganic polymer chains (insoluble metal silicates) throughout the aqueous phase. These polymer chains physically entrap the organic colloids within the microstructure of the product matrix. The water-soluble silicates then react with complex ions in the presence of a silicate setting agent, producing amorphous, colloidal silicates (gels) and silicon dioxide, which acts as a precipitating agent.

Most of the heavy metals in the waste become part of the silicate gel. Some of the heavy metals precipitate with the structure of the silicate gel. A very small percentage (estimated to be less than one percent) of the heavy metals precipitates between the silicates and is mechanically immobilized.

Since some organics may be contained in particles larger than the silicate gel, all of the waste is pumped through processing equipment, creating sufficient shear in combination with surface active chemicals to emulsify the organic

constituents. Emulsified organics are then microencapsulated and solidified and discharged to a prepared area, where the gel continues to set and stabilize. The resulting solids, though friable, microencapsulate any organic substances that may have escaped emulsification. The system can be operated at 5 to 100 percent solids in the waste feed; water is added for drier wastes. Portions of the water contained in the wastes are involved in three reactions after treatment: (1) hydration, similar to that of cement reactions; (2) hydrolysis reactions; and (3) equilibration through evaporation. There are no side streams or discharges from this process.

This technology is suitable for contaminated soils, sludges, and other solid wastes. The process is applicable to electroplating wastes, electric arc furnace dust, and municipal sewage sludge containing heavy metals such as aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc.

#### **Technology Performance**

The technology was demonstrated in March 1989 at the Portable Equipment Salvage Co., site in Clackamas, Oregon. Preliminary results are available in a Demonstration Bulletin (October 1989). The Technology Evaluation Report (TER) was published in September 1990 (EPA/540/5-89/011a). The Applications Analysis Report (AAR) was completed in May 1991 (EPA/540/A5-89/011).

From fall 1989 through winter 1990, Chemfix Technologies, Inc.'s subsidiary, Chemfix Environmental Services, Inc. (CES), applied a

high solids CHEMSET® reagent protocol approach to the treatment of about 30,000 cubic yards of heavy metal-contaminated waste. The goal of reducing leachable hexavalent chromium to below 0.5 parts per million (ppm) in the toxicity characteristics leaching procedure (TCLP) was met, as well as the goal of producing a synthetic clay cover material with low permeability (less than  $1 \times 10^{-6}$  centimeters per second). The production goal of exceeding 400 tons per day was also met. This included production during many subfreezing days in December, January, and March. In Summer 1990, CES engaged in another high solids project involving lead.

Following is a summary of the results of the demonstration:

- The Chemfix Technology was effective in reducing the concentrations of copper and lead in the TCLP extracts. The concentrations in the extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations of the untreated waste approached 14 percent.
- The volume of the excavated waste material increased from 20 to 50 percent.
- In the durability tests, the treated wastes showed little or no weight loss after 12 cycles of wetting and drying or freezing and thawing.
- The unconfined compressive strength (UCS) of the wastes varied between 27 and 307 pounds per square inch after 28 days. Permeability decreased by more than one order of magnitude.
- The air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls (PCB) during the treatment process.

- The cost of the treatment process was \$73 per ton of raw waste treated, exclusive of excavation, pretreatment, and disposal.

### Remediation Costs

Cost information is not available.

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**EmTech Solidification/Stabilization Process**  
**Organic Compounds, Heavy Metals, Ore and Grease in Soil and Sludge**

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**Technology Description**

This treatment system is capable of chemically destroying certain chlorinated organics and immobilizing heavy metals. The technology mixes hazardous wastes, cement or fly ash, water, and one of 18 patented reagents commonly known as "Chloranan." In the case of chlorinated organics, the process uses metal-scavenging techniques to remove chlorine atoms and replace them with hydrogen atoms. Metals are fixed at their lowest solubility point.

Soils, sludges, and sediments can be treated in situ or excavated and treated ex situ. Sediments can also be treated underwater. Blending is accomplished in batches, with volumetric throughput rated at 120 tons per hour.

The treatment process begins by adding Chloranan and water to the blending unit, followed by the waste and mixing for 2 minutes. The cement is added and mixed for a similar time. After 12 hours, the treated material hardens into a concrete-like mass that exhibits unconfined compressive strengths (UCS) in the 1,000 to 3,000 pounds per square inch (psi) range, with permeabilities in the  $10^{-9}$  centimeters per second range. Results may vary. It is capable of withstanding several hundred cycles of freeze and thaw weathering.

This technology has been refined since the 1987 SITE demonstration and is now capable of destroying certain chlorinated organics and also immobilizing other wastes, including very high levels of metals. The organics and inorganics can be treated separately or together with no impact on the chemistry of the process.

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**Technology Performance**

This technology was demonstrated in October 1987 at a former oil processing plant in Douglassville, Pennsylvania. The site soil contained high levels of oil and grease (250,000 ppm) and heavy metals (22,000 ppm lead), and low levels of volatile organic compounds (100 ppm) and polychlorinated biphenyls (75 ppm). An Applications Analysis Report (EPA/540/A5-89/001) and a Technology Evaluation Report (EPA/540/5-89/001a) are available. A report on long-term monitoring may be obtained from EPA's Risk Reduction Engineering Laboratory.

Since the demonstration in 1987, the technology has been greatly enhanced through the development of 17 more reagent formulations that expand dechlorination of many chlorinated organics to include PCBs, ethylene dichloride (EDC), trichlorethylene (TCE), and others.

Remediation of heavily contaminated oily soils and sludges has been accomplished, as well as remediation of a California Superfund site with up to 220,000 ppm of zinc. The Canadian Government selected this process as one to test for underwater treatment of PCBs and VOCs found in sediments.

Comparisons of the 7-day, 28-day, 9-month, and 22-month sample test results for the soil are generally favorable. The physical test results were very good, with UCS between 220 and 1,570 psi. Very low permeabilities were recorded, and the porosity of the treated wastes was moderate. Durability test results showed no change in physical strength after the wet and dry and freeze and thaw cycles. The waste volume increased by about 120 percent. However, refinements of the technology now restrict volumetric increases to the 15 to 25 percent range. Using less additives reduces

strength, but toxicity reduction is not affected. There appears to be an inverse relationship between physical strength and organic contaminant concentration.

The results of the leaching tests were mixed. The toxicity characteristics leaching procedure (TCLP) results of the stabilized wastes were very low; essentially, all concentrations of metals, VOCs, and semivolatile organics were below 1 ppm. Lead leachate concentrations dropped by a factor of 200 to below 100 parts per billion. Volatile and semivolatile organic concentrations, however, did not change from the untreated soil TCLP. Oil and grease concentrations were greater in the treated waste TCLPs (4 ppm) than in the untreated waste (less than 2 ppm).

The process can treat contaminated material with high concentrations (up to 25 percent) of oil. However, during the SITE demonstration, volatiles and base and neutral extractables were not immobilized significantly.

Heavy metals were immobilized. In many instances, leachate reductions were greater by a factor of 100.

The physical properties of the treated waste include high unconfined compressive strengths, low permeabilities, and good weathering properties.

## **Remediation Costs**

The process, based on tests at Douglassville, Pennsylvania, was economical, with costs ranging from \$40-60 per ton for processing heavy metals waste, and between \$75-100 per ton for wastes with heavy organic content.

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## **In Situ Solidification/Stabilization Process**

### **Inorganic and Organic Compounds in Soil, Sediment, and Sludge**

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#### **Technology Description**

This in situ solidification and stabilization technology immobilizes organic and inorganic compounds in wet or dry soils, using reagents (additives) to produce a cement-like mass. The basic components of this technology are: (1) Geo-Con's deep soil mixing system (DSM), a system to deliver and mix the chemicals with the soil in situ; and (2) a batch mixing plant to supply the International Waste Technologies' (IWT) proprietary treatment chemicals.

The proprietary additives generate a complex, crystalline, connective network of inorganic polymers. The structural bonding in the polymers is mainly covalent. The process involves a two-phased reaction in which the contaminants are first complexed in a fast acting reaction, and then in a slow acting reaction, where the building of macromolecules continues over a long period of time. For each type of waste, the amount of additives used varies. Treatability tests are recommended.

The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 revolutions per minute (rpm). Two conduits in the auger are used to inject the additive slurry and supplemental water. Additive injection occurs on the downstroke; further mixing takes place upon auger withdrawal. The treated soil columns are 36 inches in diameter, and are positioned in an overlapping pattern of alternating primary and secondary soil columns.

The IWT technology can be applied to soils, sediments, and sludge-pond bottoms contaminated with organic compounds and

metals. The technology has been laboratory tested on soils containing polychlorinated biphenyls (PCB), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons.

#### **Technology Performance**

A SITE demonstration was conducted at a PCB-contaminated site in Hialeah, Florida, in April 1988. Two 10-by-20-foot test sectors of the site were treated — one to a depth of 18 feet, and the other to a depth of 14 feet. Ten months after the demonstration, long-term monitoring tests were performed on the treated sectors. The Technology Evaluation Report and Applications Analysis Report have been published.

Key findings from the demonstration are summarized below:

- Immobilization of PCBs appears likely, but could not be confirmed because of low PCB concentrations in the untreated soil. Leachate tests on treated and untreated soil samples showed mostly undetectable PCB levels. Leachate tests performed one year later on treated soil samples showed no increase in PCB concentrations, indicating immobilization.
- Sufficient data were not available to evaluate the performance of the system with regard to metals or other organic compounds.
- Each of the test samples showed high unconfined compressive strength, low permeability, and low porosity. These physical properties improved when retested one year later, indicating the potential for long-term durability.

- The bulk density of the soil increased 21 percent after treatment. This increased the volume of treated soil by 8.5 percent and caused a small ground rise of one inch per treated foot of soil.
- The unconfined compressive strength (UCS) of treated soil was satisfactory, with values up to 1,500 pounds per square inch (psi).
- The permeability of the treated soil was satisfactory, decreasing four orders of magnitude compared to the untreated soil, or  $10^{-6}$  and  $10^{-7}$  compared to  $10^{-2}$  centimeters per second.
- The wet and dry weathering test on treated soil was satisfactory. The freeze and dry weathering test of treated soil was unsatisfactory.
- The microstructural analysis, scanning electron microscopy (SEM), optical microscopy, and x-ray diffraction (XRD), showed that the treated material was dense and homogeneously mixed.

Following is a summary of the applications analysis:

- Microstructural analyses of the treated soils indicated a potential for long-term durability. High unconfined compressive strengths and low permeabilities were recorded.
- Data provided by IWT indicate some immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the IWT reagent. There are insufficient data to confirm this immobilization.
- Performance data are limited outside of SITE demonstrations. The developer modifies the binding agent for different wastes. Treatability studies should be performed for specific wastes.

## Remediation Costs

Costs for this process are estimated at \$194 per ton for the 1-auger machine used in the demonstration and \$111 per ton for a commercial 4-auger operation.

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## **NOMIX® Technology**

### **Metals in Waste Lagoons and Spills**

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#### **Technology Description**

The NOMIX® technology is a patented solidification and stabilization process that can be applied to contaminated media in situ, without the need for mixing or equipment. The technology combines specially formulated cementitious materials with waste media. Because the material hardens faster than conventional concrete, there is a savings in remediation time.

The NOMIX® solidification compounds consist of specially formulated cements, sands, aggregates, and various combinations thereof. The dry components and their reacting rates with the wet waste are closely controlled, allowing rapid and efficient solidification. The contaminated media may be diluted with water, if necessary, to facilitate the solidification process. If the addition of water is necessary, it may be introduced into the waste media before the addition of the preblended solidification compounds in various ways to create a homogenous solution of waste and water. The solidification compounds are then poured through the waste and water solution in a consistent manner, allowing the complete absorption of the waste solution and the formation of a solid mass. The process produces a relatively homogenous treated mass compared to that produced by solidification processes using mixing equipment.

Applications of the technology require little labor and, because mixing is accomplished simply by pouring the solidification compounds through the waste combination, greater quantities of waste can be solidified by this process than with normal concrete mixtures. The treated waste is a hardened mass which, according to bench-scale data, can be made

relatively impermeable with formulation adjustments or coatings when compared with the treated product from systems using formulations of regular concrete mixes, such as ASTM C-109 standard mix.

The process can address contaminated waste contained in drums (or other containers), a minor spill, or even a lagoon. Each of these situations will require its own particular installation procedures. After solidification, the units can be moved for storage, or left in place for normal situations. For critical situations, the solidified mass may be encased for extra protection with a non-shrink, structural concrete, and/or a high quality waterproof coating.

The NOMIX® technology is currently most suitable for solidification and stabilization of aqueous wastes in the following situations:

- Solidification of drum waste
- Solidification of minor spills in situ to minimize soil, facility, or plant contamination
- Solidification of waste lagoons for long-term, in-place storage, or for solidification in preparation for removal.

The technology has been applied to solutions of mercuric chloride, nickel sulfate, phenylene diamene, barium acetate, lead, and phenol. These samples were analyzed using the proven procedures of ASTM Standard C-109, and the resulting strengths were similar to those expected from a standard concrete mix.

As the technology is improved it will become suitable for solidification of various wastes in soils including inorganic wastes.

### **Technology Performance**

Solidification and stabilization using the NOMIX® Technology was accepted into the SITE Demonstration Program in March 1991. The date and place of the demonstration are undetermined.

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## **SAREX Chemical Fixation Process**

### **Low-Level Metals and Organics in Soil and Sludge**

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#### **Technology Description**

The SAREX chemical fixation process (CFP), developed by Separation and Recovery Systems, Inc. (SRS), is a thermal and chemical reactive (fixation) process that removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC), and the remaining constituents of organic and inorganic sludge materials in a stable matrix. SAREX CFP uses specially prepared lime and proprietary, nontoxic chemicals (a reagent blend) mixed proportionally to catalyze and control the reactions. The treated product displays chemical properties which conform to toxic EPA standards for resource recovery and site restoration. The product also exhibits high structural integrity, with a fine, granular, soil-like consistency, of limited solubility. It is free flowing until compacted (50 to 80 pounds per square inch), isolating the remaining constituents from environmental influences.

Depending on the characteristics of the waste material, it may be covered with a liquid neutralizing reagent that initiates the chemical reactions and helps prevent vapor emissions. If required, the waste material may be moved to the neutralization (blending) tank where a "make-up" reagent slurry is added, depending on material characteristics. The waste is placed on the feed hopper.

The reagent is measured and placed on the transfer conveyor so that the reagent and waste mixture would advance to the single-screw homogenizer, where it is thoroughly blended to a uniform consistency. The reagent blend reacts exothermally with the hazardous constituents to initiate the removal of the VOCs and SVOCs. The process, now about 70 percent complete, continues in the multi-screw, jacketed, non-

contacting processor for curing (a predetermined curing time allows reactions to occur within a controlled environment). In the processor, the mixture can be thermally processed at a high temperature to complete the process. The processed material exits the processor onto a discharge conveyor for movement into SRS-designed sealed transport containers for delivery to the end use.

Contaminants loss into the air (mobility) during processing is eliminated by use of a specially designed SAREX vapor recovery system and processed prior to release into the air. Dust particles are removed in a baghouse, and the vapors are routed through a series of water scrubbers, which cool the vapors (below 120°F) and remove any condensates. The vapors then pass through two demisters and a positive displacement blower to remove additional condensates. A freon chilling unit (37°F or 0°F) cools the remaining vapors, which are sent to a storage tank. The final vapor stream is polished in two charcoal vapor packs before being emitted into the air.

The SAREX CFP may be applied to a wide variety of organic and inorganic materials. These include sludges that contain high concentrations of hazardous constituents, with no upper limit of oil or organic content. No constituents interfere with the fixation reactions, and water content is not an obstacle, although there may be steaming caused by the exothermic reactions. The following material types can be processed by the SAREX CFP:

- Large crude oil spills
- Refinery sludges
- Hydrocarbon-contaminated soils
- Lube oil acid sludges
- Tars

In addition, metals are captured within the treated matrix and will pass the toxicity characteristics leaching procedure (TCLP). This proves to be advantageous, because most on-site cleanup programs focus on sludge ponds or impoundments that have received many different types of compounds and debris over several years.

### **Technology Performance**

During the development of the SAREX CFP technology, data has been gathered from laboratory analysis, process demonstrations, and on-site projects. Samples of sludges from two ponds were analyzed for surface and bottom characteristics. After treatment of the samples, the products were analyzed in powder and molded pellet form.

A field demonstration was conducted during 1987 at a midwest refinery by treating approximately 400 cubic yards of lube oil acid sludges. Two projects each were completed in the midwest, California, and Australia.

SRS expects to conduct a SITE demonstration during 1992. EPA is seeking a suitable site for the demonstration.

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## **Solidification of Spent Blasting Heavy Metals in Spent Blasting Abrasives, Grit, and Sands**

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### **Technology Description**

In this process, abrasives are screened and mixed with asphalt and other aggregates. Target contaminants are lead and copper.

The goal of this technology is to recycle spent abrasives into non-hazardous product that can be reused as valuable commercial product available for unrestricted public use. The process produces less than one percent inert debris (wood and metal scrap). Treatment capacity varies with the plant.

### **Technology Performance**

A field demonstration of this technology was conducted at the Naval Construction Battalion Center at Port Hueneme, California, from February 1991 through February 1992. The test involved 1,200 tons of blasting paint from vehicles.

### **Remediation Costs**

Costs for use of this process are estimated at \$85 per ton of waste. Approximately two months are required for design.

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## **Solidification/Stabilization**

### **Organics and Inorganics in Soil, Sludge, and Liquid**

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#### **Technology Description**

This solidification and stabilization technology applies proprietary bonding agents to soils, sludge, and liquid wastes with organic and inorganic contaminants to treat the pollutants within the wastes. The waste and reagent mixture is then mixed with cementitious materials, which form a stabilizing matrix. The specific reagents used are selected based on the particular waste to be treated. The resultant material is a nonleaching, high-strength monolith.

The process uses standard engineering and construction equipment. Since the type and dose of reagents depend on waste characteristics, treatability studies and site investigations must be conducted to determine the proper treatment formula. The process begins with excavation of the waste. Materials containing large pieces of debris must be prescreened. The waste is then placed into a high shear mixer, along with premeasured quantities of water and SuperSet®, WASTECH's proprietary reagent.

Next, cementitious materials are added to the waste-reagent mixture, stabilizing the waste and completing the treatment process. WASTECH's treatment technology does not generate waste by-products. The process can also be applied in situ.

WASTECH's technology can treat a wide variety of waste streams consisting of soils, sludges, and raw organic streams, such as lubricating oil, aromatic solvents, evaporator bottoms, chelating agents, and ion exchange resins, with contaminant concentrations ranging from part per million levels to 40 percent by volume. The technology can also treat wastes

generated by the petroleum, chemical, pesticide, and wood-preserving industries, as well as wastes generated by many other manufacturing and industrial processes. WASTECH's technology can also be applied to mixed wastes containing radioactive materials, along with organic and inorganic contaminants.

#### **Technology Performance**

This technology was accepted into the SITE Demonstration Program in Spring 1991. Bench-scale evaluation of the process is complete. A field demonstration at Robins Air Force Base in Macon, Georgia, was completed in August 1991. The WASTECH technology was used to treat high level organic and inorganic wastes at an industrial sludge pit. The technology is now being commercially applied to treat hazardous wastes contaminated with various organics, inorganics, and mixed wastes.

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## **Solidification/Stabilization with Silicate Compounds Organics and Inorganics in Ground Water, Soil, and Sludge**

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### **Technology Description**

Silicate Technology Corporation's (STC) technology for treating hazardous waste utilizes silicate compounds to solidify and stabilize organic and inorganic constituents in contaminated soils, sludges, and wastewater.

STC's organic chemical fixation/solidification technology involves the bonding of the organic contaminants into the layers of the of an alumino silicate compound. STC's inorganic chemical fixation/solidification technology involves the formation of insoluble chemical compounds which reduces the overall reagent addition compared to generic cementitious processes.

Pretreatment of contaminated soil includes separation of coarse and fine waste materials, and the crushing of coarse material, reducing it to the size required for the solidification and stabilization technology. The screened waste is weighed and a predetermined amount of silicate reagent is added. The material is conveyed to a pug mill mixer where water is added and the mixture is blended. Sludges are placed directly into the pug mill for addition of reagents and mixing. The amount of reagent required for solidification and stabilization can be adjusted according to variations in organic and inorganic contaminant concentrations determined during treatability testing. Treated material is placed in confining pits for on-site curing or cast into molds for transport and disposal off site.

STC's technology has been successfully implemented on inorganic and organic contaminated hazardous remediation projects, inorganic and organic industrial wastewater treatment systems, industrial in-process treatment, and RCRA landban treatment of F006

and K061 wastes. A typical remediation project would include pretreatment of the waste which consists of screening and crushing operations.

STC's technology can be applied to a wide variety of hazardous soils, sludges, and wastewaters. Applicable waste media include the following:

- Inorganic contaminated soils and sludges. Contaminants including most metals, cyanides, flourides, arsenates, chromates, and selenium.
- Organic contaminated soils and sludges. Organic compounds including halogenated aromatics, polycyclic aromatic hydrocarbons (PAHs), and aliphatic compounds.
- Inorganic and organic contaminated wastewaters. Heavy metals, emulsified and dissolved organic compounds in ground water and industrial wastewater, excluding low-molecular-weight organic contaminants such as alcohols, ketones, and glycols.

### **Technology Performance**

Under the SITE Demonstration Program, the technology was demonstrated in November 1990 at the Selma Pressure Treating (SPT) wood preserving site in Selma, California. The SPT site was contaminated with both organics, mainly pentachlorophenol (PCP), and inorganics, mainly arsenic, chromium and copper. The Applications Analysis Report and Technology Evaluation Report is expected to be published in 1992.

Following is a summary of the results of the demonstration:

- STC's technology can treat PCP. Extract and leachate concentrations of PCP were reduced by up to 97 percent.
- The technology can immobilize arsenic. Toxicity characteristic leaching procedure (TCLP) and TCLP-distilled water leachate concentrations were reduced by up to 92 and 98 percent, respectively.
- The technology can immobilize chromium and copper. Initially low TCLP and TCLP-distilled water leachate concentrations of chromium (0.07 to 0.27 ppm) were reduced by up to 54 percent. Initial TCLP and TCLP-distilled water leachate concentrations of copper (0.4 ppm and 9.4 ppm) were reduced by up to 99 and 90 percent, respectively.
- Immobilization of semivolatile organic compounds and volatile compounds other than PCP could not be evaluated due to the low concentrations of these analytes in the wastes.
- Treatment of the wastes resulted in volume increases ranging from 59 to 75 percent (68 percent average).
- After a 28-day curing period, the treated wastes exhibited moderately high unconfined compressive strengths of 260 to 350 pounds per square inch.
- Permeability of the treated waste was low (less than  $1.7 \times 10^{-7}$  centimeters per second). The relative cumulative weight loss after 12 wet and dry and 12 freeze and thaw cycles was negligible (less than 1 percent).

### **Remediation Costs**

STCs technology is expected to cost approximately \$200 per cubic yard when used to treat large amounts (15,000 cubic yards) of waste similar to that found at the SPT demonstration site.

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## **Soliditech Solidification/Stabilization Process**

### **Organic and Inorganic Compounds, Metals, Ore and Grease in Soil and Sludge**

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#### **Technology Description**

This solidification and stabilization process immobilizes contaminants in soils and sludges by binding them in a concrete-like, leach-resistant matrix.

Contaminated waste materials are collected, screened to remove oversized material, and introduced to the batch mixer. The waste material is then mixed with (1) water, (2) Urrichem — a proprietary chemical reagent, (3) proprietary additives, and (4) pozzolanic material (fly ash), kiln dust, or cement. After it is thoroughly mixed, the treated waste is discharged from the mixer. Treated waste is a solidified mass with significant unconfined compressive strength, high stability, and a rigid texture similar to that of concrete.

This technology is intended for treating soils and sludges contaminated with organic compounds, metals, inorganic compounds, and oil and grease. Batch mixers of various capacities are available to treat different volumes of waste.

#### **Technology Performance**

The process was demonstrated in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. This location formerly contained both chemical processing and oil reclamation facilities. Wastes treated during the demonstration were soils, filter cake, and oily wastes from an old storage tank. These wastes were contaminated with petroleum hydrocarbons, polychlorinated biphenyls (PCBs), other organic chemicals, and heavy metals.

Key findings from the Soliditech demonstration are summarized below:

- Chemical analyses of extracts and leachates showed that heavy metals present in the untreated waste were immobilized.
- The process solidified both solid and liquid wastes with high organic content (up to 17 percent), as well as oil and grease.
- Volatile organic compounds in the original waste were not detected in the treated waste.
- Physical test results of the solidified waste samples showed: (1) unconfined compressive strengths ranging from 390 to 860 pounds per square inch (psi); (2) very little weight loss after 12 cycles of wet and dry and freeze and thaw durability tests; (3) low permeability of the treated waste; and (4) increased density after treatment.
- The solidified waste increased in volume by an average of 22 percent. Because of solidification, the bulk density of the waste material increased by about 35 percent.
- Semivolatile organic compounds (phenols) were detected in the treated waste and the Toxicity Characteristic Leachate Procedure (TCLP) extracts from the treated waste, but not in the untreated waste or its TCLP extracts. The presence of these compounds is believed to result from chemical reactions in the waste treatment mixture.
- Oil and grease content of the untreated waste ranged from 2.8 to 17.3 percent (28,000 to 173,000 ppm). Oil and grease content of the TCLP extracts of the solidified waste ranged from 2.4 to 12 ppm.
- The pH of the solidified waste ranged from 11.7 to 12.0. The pH of the untreated waste ranged from 3.4 to 7.9.

- PCBs were not detected in any extracts or leachates of the treated waste.
- Visual observation of solidified waste contained dark inclusions about 1 millimeter in diameter. Ongoing microstructural studies are expected to confirm that these inclusions are encapsulated wastes.

Technology Developer Contact:  
 Bill Stallworth  
 Soliditech, Inc.  
 1325 S. Dairy Ashford, Suite 385  
 Houston, TX 77077  
 713/497-8558

A Technology Evaluation Report was published in February 1990 in two volumes. Volume I (EPA/540/5-89/005A) is the report; Volume II (EPA/540/5-89/005B) contains data to supplement the report. An Applications Analysis Report was published in September 1990 (EPA/4540/A5-89/005).

## Contacts

EPA Project Manager:  
 S. Jackson Hubbard  
 U.S. EPA  
 Risk Reduction Engineering Laboratory  
 26 West Martin Luther King Drive  
 Cincinnati, OH 45268  
 513/569-7507



## **Stabilization of Small Arms Range Soils Lead in Soil**

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### **Technology Description**

In this process, contaminated soil is treated ex situ. The soil is removed and screened to remove bullets and other debris. Bullets screened out in this phase of the treatment are recycled; other debris is disposed of in a landfill.

Screened soil is then mixed with sodium silicate, portland cement, and water. The mixture is then cured and treated soil is returned to its original location.

Target contaminants for this technology are heavy metals, particularly lead. The goal of the process is to reduce levels of lead to less than EPA criteria.

### **Remediation Costs**

Estimated cost for use of this technology was \$490 per ton of waste.

### **Contacts**

Barbara Nelson and Jeff Heath  
Naval Civil Engineering Laboratory  
Code L71  
Port Hueneme, CA 93043  
805/982-1668

Dr. Jeffrey Means  
Battelle Memorial Institute  
505 King Avenue  
Columbus, OH 43201-2693  
614/424-5442

### **Technology Performance**

A field demonstration of this process was conducted in 1990 at the Small Arms Range at Naval Air Station Mayport in Florida. Approximately 170 cubic yards of contaminated soil was successfully treated in the demonstration. TCLP levels of lead, copper, and zinc were reduced — from 720 ppm to less than 0.9 ppm for lead; from 7 ppm to less than 0.2 ppm for copper; and from 4.1 ppm to less than 0.2 ppm for zinc.

## **Stabilization with Lime**

### **Hydrocarbons and Organics in Sludge**

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#### **Technology Description**

This technology uses lime to stabilize acidic sludge containing at least five percent hydrocarbons (typical of sludge produced by recycling lubricating oils). The technology can also stabilize waste containing up to 80 percent organics. The process tolerates low levels of mercury and moderate levels of lead and other toxic metals. No hazardous materials are used in the process. The lime and other chemicals are specially prepared to significantly improve their reactivity and other key characteristics.

Sludge is removed from a waste pit using conventional earthmoving equipment and mixed with lime in a separate blending pit. The temperature of the material in the blending pit rises for a brief time to about 100°C, creating some steam. After 20 minutes, almost all of the material is fixed, however, the chemicals mixed in the sludge continue to react with the waste for days. The volume of the waste is increased by 30 percent by adding lime.

The fixed material is stored in a product pile until the waste pit has been cleaned. The waste is then returned to the pit and compacted to a permeability of  $10^{-10}$  cm/sec.

#### **Technology Performance**

EPA is seeking a suitable site to demonstrate this technology. A SITE demonstration is planned for the spring or summer of 1991.

#### **Remediation Costs**

Cost information is not available.

#### **Contacts**

EPA Project Manager:  
Walter Grube  
U.S. Environmental Protection Agency  
Risk Reduction Engineering Laboratory  
26 West Martin Luther King Drive  
Cincinnati, Ohio 45268  
513/569-7798

Technology Developer Contact:  
Joseph DeFranco  
Separation and Recovery Systems, Inc.  
1762 McGaw Avenue  
Irvine, California 92714  
714/261-8860

## ***Appendix B***

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# **General Technology Development Programs**

## Mixed Waste Landfill

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The mission of the Mixed-Waste Landfill Integrated Demonstration (MWLID) is to demonstrate in contaminated sites new technologies for cleanup of chemical and mixed waste landfills that are representative of many sites occurring through the DOE complex and the nation. When implemented, these new technologies promise to characterize and remedy past waste disposal practices that have led to contaminated landfill sites across the country. Characterization and remediation technologies are aimed at making cleaning up less expensive, safer, and more effective than current techniques. This will be done by emphasizing "in situ" technologies. Soils will not be moved while the extent of the contamination is assessed (characterized), and the threat from the contaminant will be safely mitigated. Most important, the MWLID's success will be shared with other Federal, state, and local governments, and private industry that face the important task of remediation of waste sites.

### General Site Information

MWLID will demonstrate technology at two landfills at Sandia National Laboratories, Albuquerque, New Mexico. The Chemical Waste Landfill received hazardous (chemical) waste from the laboratory from 1962 to 1985, and the Mixed-Waste Landfill received hazardous waste and radioactive wastes (mixed wastes) over a 29-year period (1959-1988) from various Sandia nuclear research programs.

Both landfills now are closed. Originally, however, the sites were selected because of Albuquerque's arid climate and the thick layer of alluvial deposits that overlay ground water approximately 480 feet below the landfills. This thick layer of "dry" soils, gravel, and clays promised to be a natural barrier between the landfills and ground water.

Prior to May 1992, field demonstrations of the characterization technologies were performed at an un-contaminated site near the Chemical Waste Landfill. In May, DOE initiated demonstration in the Chemical Waste Landfill with non-intrusive characterization techniques. Future characterization plans include technology demonstrations in stages — first at the Chemical Waste Landfill and then at the Mixed Waste Landfill.

Bench-scale demonstrations of electrokinetic remediation methods have been completed by Sandia. A pilot field demonstration will occur in 1993 at an un-contaminated site.

The first phase of the Thermally Enhanced Vapor Extraction System (TEVES) project occurred in 1992 when two holes were drilled and vapor extraction wells were installed at the Chemical Waste Landfill. Three types of technology to remediate volatile organic chemicals (VOCs) in soils are involved in this demonstration. Obtaining the engineering design and environmental permits necessary to implement this field demonstration will take until May 1993. Field demonstration of the vapor extraction system will occur from May through December 1993.

### Contact

Lynn Tyler  
Sandia National Laboratories  
P.O. Box 5800  
Division 6621  
Albuquerque, NM 87185-5800  
505/845-8348

## Organics in Soils and Ground Water at Non-Arid Sites

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This integrated demonstration program is developing, demonstrating, and comparing technologies for remediation of volatile organics (e.g., TCE, PCE) in soils and ground water at non-arid DOE sites. The demonstration provides for technical performance comparisons of different available technologies at one specific site, based on cost effectiveness, risk reduction effectiveness, technology effectiveness, and general acceptability. Specifically, the demonstration involves characterization, off-gas treatment techniques, and other technologies associated with the remediation of soils and ground water contaminated with volatile organics. The demonstration will also establish control and performance prediction methods for the individual technologies so they can be scaled up for full-scale remediation programs. Technology transfer to governments agencies and the industrial sector is a critical facet of the DOE demonstration program.

Directional drilling is being demonstrated as a tool to improve access to the subsurface for characterization, monitoring, and remediation. Access under existing facilities can only be acquired using directional drilling. Existing technologies from other industries are being modified and hybridized for environmental applications.

Characterization technologies already demonstrated include depth-discrete soil and ground-water sampling, cone penetrometer with real-time analytical capabilities, and nucleic acid probes for microbial characterization.

Monitoring technologies demonstrated include geophysical tomography, fluid flow sensors, fiber optic chemical sensors, real-time field analytical methods, and multi-level vadose zone and ground-water samplers.

Remediation technologies include in situ air stripping (air sparging), in situ bioremediation, and radio frequency heating.

Off-gas treatment technologies such as photocatalytic oxidation, catalytic oxidation, biotreatment, ion beam oxidation, steam reforming, membrane separation, and UV oxidation also are involved in the demonstration.

### General Site Information

This demonstration program is being conducted at DOE's Savannah River Site in Aiken, South Carolina. The Savannah River Site is located on the upper Atlantic Coastal Plain. The site is underlain by a thick wedge of unconsolidated Tertiary and Cretaceous sediments that overlay the basement, which consists of preCambrian and Paleozoic metamorphic rocks and consolidated Triassic sediments. Ground-water flow at the site is controlled by hydrologic boundaries: flow at and immediately below the water table is to local tributaries; and flow in the lower aquifer is to the Savannah River or one of its major tributaries. The water table is located at approximately 135 feet. Ground water in the vicinity of the process sewer line contains elevated concentrations of TCE and PCE to depths of greater than 180 feet.

### Contact

Terry Hazen  
Westinghouse Savannah River Company  
Savannah River Laboratory  
Environmental Sciences Section  
Aiken, SC 29802  
803/725-6211

## Volatile Organic Compounds at Arid Sites

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This integrated demonstration program will develop and compare technologies for removal/destruction of volatile organics (e.g., TCE, PCE) in arid sites. Control and performance prediction methods must be applicable to arid zones or environments with large vadose zones. The program will cover all phases involved in an actual cleanup, including all regulatory and permitting requirements, expediting future selection and implementation of the best technologies to show immediate and long-term effectiveness. The demonstration provides for technical performance comparisons of different available technologies at one specific site based on cost effectiveness, risk reduction effectiveness, technology effectiveness, and applicability.

Technologies in this integrated demonstration include steam reforming, supported liquid membrane separation, membrane separation, in situ bioremediation, in situ heating, and in situ corona destruction.

The demonstration also involves development of field screening and real-time measurement capability and enhanced drilling, such as sonic drilling.

### General Site Information

The site for this demonstration program consists of about 560 square miles of semi-arid terrain at DOE's Hanford Reservation. The test location contains primarily carbon tetrachloride, chloroform, and a variety of associated mixed waste contaminants. About 1,000 metric tons of carbon tetrachloride were discharged at waste disposal cribs between 1955 and 1973. Chemical processes to recover and purify plutonium at Hanford's plutonium finishing plant resulted in the production of actinide-bearing waste liquid. Both aqueous and organic liquid wastes were generated, and routinely discharged to subsurface disposal facilities. The primary radionuclide in the waste streams was plutonium, and the primary organic was carbon tetrachloride.

### Contact

Steve Stein  
Environmental Management Organization  
Pacific Northwest Division  
4000 N.E. 41st Street  
Seattle, WA 98105  
206/528-3340

## Underground Storage Tanks

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The Underground Storage Tank Integrated Demonstration (UST-ID) was created in February 1991 to develop unique state-of-the-art and advanced state-of-the-art technologies that can be applied to ongoing and planned environmental programs at sites across the DOE complex. The UST-ID is necessary to enable a final decision on disposal of underground storage tank wastes and soils, ground water, and ancillary equipment. Six technical focus areas have been formed under the UST-ID program:

- Characterization
- Retrieval, transfer, and storage
- Waste separation
- High-level and low-level waste treatment
- In situ treatment and disposal
- Site closure.

Currently, the UST-ID program emphasizes technologies that provide near-term benefits toward remediation of USTs. This approach will garner end-user program support and foster synergy between the UST-ID program and the end-user programs. Fiscal Year 1992 efforts have been directed toward the first three areas, which are shared by most of the participant sites. (Smaller investments are dedicated to the remaining focus areas, but these areas are nonetheless critical.)

Characterization of tank wastes has traditionally been limited by high analytical costs and the inability to obtain data from many points in the tanks. Hence, tasks have been selected to develop sensors that will decrease laboratory analytical time, and to develop a means for deploying these sensors inside the tank. Laser Raman spectroscopic sensors being developed will first be used in the analytical laboratory and, when proven, will be configured for in-tank use.

Waste retrieval techniques will be tested using a light-duty utility arm. Designed for in situ deployment, this articulated, remotely operated arm will deploy characterization devices and test some features of waste retrieval technology on actual tank waste. It is expected that this arm will be able to deliver characterization tools, such as optical sensors and physical measurement devices, to obtain data of much higher statistical certainty than is presently possible.

Waste separation work represents heavy investment in technologies with high probability for success. Smaller efforts are expended for development of advanced techniques that have high potential payoff. A long-term strategy has been developed to feed demonstrated separation techniques to the user according to the user schedule. (See demonstration description on page 60.)

As one of DOE's largest integrated demonstrations, the UST-ID reviewed approximately 100 technologies during 1991. Thirty-four technologies were selected for further development and evaluation.

### General Site Information

The technologies developed in the UST-ID program will be used in remediation actions at five participating DOE sites: Hanford, Fernald, Idaho, Oak Ridge, and Savannah River. The five sites began operations between 1943 and the early 1950s. They originally supported nuclear fuels production, operations, and research programs as part of the development of nuclear weapons subsequent to World War II. Most of the site missions have evolved from production to peaceful uses of nuclear power, research and development, and environmental cleanup.



A variety of processes were used to produce nuclear fuels (enriched uranium, plutonium, and tritium production and recovery process) at these sites. Most UST waste was generated by the processes used to separate nuclear fuels from other components. In the tanks, separation chemicals mixed with the fission and decay products generated in the initial production step. Early separation processes generated high concentrations of waste (64.5 m<sup>3</sup> waste per ton of product [117,000 gal/ton]). Modern processes have been designed to minimize waste; most generate relatively small concentrations (1.14 m<sup>3</sup> waste per ton of product [300 gal/ton]).

The major emphasis of the UST-ID is the single-shell storage tanks located at the Hanford site, located in the southeastern section of Washington State near the cities of Richland, Kennewick, and Pasco. It has operated since 1943 with a primary mission of producing plutonium isotopes. Plutonium was produced by irradiation of enriched uranium in eight nuclear reactors located along the Columbia River. The plutonium was separated from the remaining uranium and fission products by chemical processes. It was then sent offsite for further purification.

The waste generated by the different chemical separation processes has been stored in 177 USTs for future retrieval and treatment for final disposal. There are eight UST design types, ranging in age from six to 49 years. Of the 177 USTs, 149 are of a single carbon steel shell with a reinforced concrete shell. The remaining 28 have dual carbon steel liners, and range in capacity from 208 to 3,785 m<sup>3</sup> (55,000 to 1 million gal). Approximately 225,000 m<sup>3</sup> (59.4 million gal) of high-level waste is stored in the USTs. The waste has four general physical forms: sludge, supernatant (liquid), salt cake, and slurry. All of the waste is alkaline with a large percentage of sodium nitrate and nitrate salts and metal oxides. The principle radionuclides include <sup>235</sup>U, <sup>238</sup>U, <sup>239</sup>Pu, and the uranium fission products <sup>90</sup>Sr and <sup>137</sup>Cs, as well as their decay products.

### Contact

Roger Gilchrist  
Technology Demonstration Program  
Westinghouse Hanford Company  
2355 Stevens Drive  
P.O. Box 1970, MS L5-63  
Richland, WA 99352  
509/376-5310

## Uranium Soils

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The objectives of this integrated demonstration are to:

- Demonstrate advanced technologies to decontaminate uranium-contaminated soils;
- Demonstrate advanced technologies for field characterization and precision excavation;
- Demonstrate a system of advanced technologies that will work effectively together to characterize, excavate, decontaminate, and dispose of remaining wastes for uranium-contaminated soils; and
- Provide a transfer of these technologies into DOE restoration programs and the private sector.

The demonstration is expected to be conducted throughout three years with the results feeding directly into the Fernald Environmental Management Project (FEMP) remediation process. Community relations activities will be conducted as part of the integrated demonstration in conjunction with the community relations activities currently ongoing under the FEMP CERCLA Program.

The integrated demonstration focuses on more than just the decontamination process. It has been organized to focus in six key areas:

- Characterization
- Excavation technologies
- Decontamination processes
- Secondary waste treatment
- Performance assessment
- Regulations

Several research and development efforts will be supported for longer term results; however, the integrated demonstration will concentrate

primarily on technologies already developed but as yet undemonstrated in an field application.

The project will demonstrate new soil remediation technologies with the potential to reduce clean-up costs and time through effective waste management. The demonstration provides for technical performance comparisons of different available technologies at one specific site based on cost effectiveness, risk reduction effectiveness, technology effectiveness, and general applicability. Enhanced site characterization and precise excavation technologies will be combined with advanced uranium soil decontamination processes to produce a technology system for use at the FEMP and through the DOE complex for similar contamination cleanups.

The characterization sub-project within the integrated demonstration is focusing on technologies which will be able to deliver real-time results in the field. The sub-project already demonstrated mapping of surface soil uranium content using real-time gamma ray spectroscopy. This technology, along with three other processes — such as Mobile Laser Ablated Inductively Coupled Plasma Optical Emission Spectrometry (MLA-ICP-OES) — will be demonstrated.

Two site locations were selected based on initial characterization data for the collection of bulk samples for treatability test. Sixteen drums of soil were excavated, screened, and blended to obtain sixteen homogenous drums from each location. The bulk samples were broken into aliquots which were shipped to multiple sites to initiate treatability tests. Treatability tests have been initiated on physical size fractionation, density gradient separation, carbonate leaching, citrate leaching, and biochealator extraction.

## **General Site Information**

This integrated demonstration is being conducted at DOE's Fernald Site, where uranium is the principal soil contaminant. The Fernald Site is located on 1,050 acres near the Great Miami River, 18 miles northwest of Cincinnati, OH. Established in the early 1950s, the production complex was used for processing uranium and its compounds from natural uranium ore concentrates. The past mission of the facility was key to national security as the primary production site for uranium metal for defense projects.

Following discontinuation of production at Fernald in 1989, environmental restoration became the mission of the site. During the 38 years of operations, the Fernald Site production area soils received varying amounts of uranium contamination resulting from accidental spills and emissions.

The technical strategy adopted by the CERCLA program is to divide the site into five distinct operable units:

- OU1 — Waste pits 1-6, Clearwell and Burn Pit
- OU2 — Other waste units (fly ash pile/solid waste landfill)
- OU3 — Production area
- OU4 — Silos 1, 2, 3, and 4
- OU5 — Environmental media

Contaminated soil exists to some degree in the majority of the operable units. Site soils are composed of clays, sands, and silts in widely varying proportions. The chemical and physical form of the uranium contamination varies with location and soil type.

## **Contact**

Kimberly Nuhfer  
Westinghouse Environmental Management  
Company of Ohio  
P.O. Box 398704  
Cincinnati, OH 45239-8704  
513/738-6677

## Treatment of Copper Industry Waste

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The primary copper industry is one of the largest generators of mining and mineral-processing wastes. While most of the generated waste materials pose no threat to the environment, some may be subject to regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA) because of their toxic corrosive characteristics. These wastes may include slags, sludges, dusts, and liquids. They often contain toxic and heavy-metal contaminants as well as metal values which are presently discarded.

The Bureau of Mines, at the Salt Lake Research Center, is developing technology to recover valuable components from these materials and stabilize the toxic constituents in environmentally-safe forms. Recent investigations have been directed toward the co-processing of two waste streams: (1) an arsenic-laden smelter flue dust; and (2) the acidic bleed solution from an electrolytic copper refinery. Acid in the refinery waste is used to solubilize the metals in the flue dust, and valuable components are subsequently recovered using hydrometallurgical techniques.

The vitrification of arsenic sulfide, removed from refinery effluents and acid-plant blowdown solutions, in a dense, non-reactive, glass-like material has also been studied in an effort to provide an environmentally safe option for disposing of arsenic.

### Contact

K.S. Gritton  
Supervisory Metallurgical Engineer  
U.S. Bureau of Mines  
Salt Lake City Research Center  
729 Arapen Drive  
Salt Lake City, UT 84108  
801/524-6158

## Characterization and Treatment of Contaminated Great Lakes Sediments

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The Contaminated Great lakes Sediments Metals Characterization and Treatment project is being performed under an Interagency Agreement between the Bureau of Mines and the U.S. Environmental Protection Agency (EPA). Work commenced in april 1990 by the Bureau's Minerals Separations research group at the Salt Lake City Research Center (SLRC).

The project has been conducted in cooperation with the Engineering-Technology Work Group in the Assessment and Remediation of Contaminated Sediments (ARCS) program. It is designed to investigate common mineral processing technologies as removal or remediation alternatives for contaminated sediments.

The ARCS program is a five-year effort authorized by the Water Quality Act of 1987. Under this program, EPA's Great Lakes National Program Office (GLNPO) is studying the removal of toxic pollutants from sediments in the Great Lakes system. The objectives of the ARCS program are to assess the extent of sediment pollution in designated areas of concern and to identify and demonstrate options for the removal and/or treatment of the contaminated sediments. The ARCS program is to be completed in 1992.

In the Characterization and Treatment project, the SLRC has studied sediments received from three sites in the Great Lakes identified as priority areas of concern: Buffalo River, NY, on Lake Erie; Indiana Harbor-Grand Calumet River, IN, on Lake Michigan; and Saginaw River, MI, on Lake Huron. The samples contain both organic and inorganic contamination.

The SLRC program was originally aimed at inorganic heavy metals such as arsenic, cadmium, chromium, copper, iron, lead,

mercury, nickel, and zinc. On request from EPA, certain organic contaminants are followed when encouraging results are obtained on heavy metals.

Preliminary tests indicated a substantial reduction in the material needing expensive treatment could be achieved by separating contaminants into a small, heavily contaminated concentrate and a larger, clean fraction, based on size classification technology. (See demonstration description on page 55.)

### Contact

J.P. Allen  
Principal Investigator  
U.S. Bureau of Mines  
Salt Lake City Research Center  
729 Arapen Drive  
Salt Lake City, UT 84108  
801/524-6147

## Borehole Slurry Extraction

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The borehole miner was developed about 10 years ago to remotely extract a finite ore body with minimal environmental disturbance. Although developed specifically as a mining tool, the concept would be equally applicable to extracting contaminated material, such as might be present under a leaking fuel tank or surrounding a contaminated well.

Successful prototype mining tests have been conducted on uranium ore, oil sands, and phosphate ore. Because system operation depends on reducing the material to a pumpable slurry in situ, it is applicable to sandstone, soil, or clay-like sediments. In most cases, material to be removed for contamination remediation would be of the proper consistency.

The system operates through a single borehole, which extends down through the material to be extracted. Prototype tools have been constructed to fit into hole diameters of 6 to 12 inches. One or more water jet nozzles direct cutting streams radially from the tool to erode an underground cavity, roughly cylindrical in shape. The slurrified material settles toward the bottom of the cavity where it is pumped to the surface by means of an eductor (jet pump), which is integral with the tool.

On the surface, the slurry is treated to remove the values. This is usually preceded by a dewatering step involving settling ponds and thickeners. In a remedial operation, it would be at this stage that the material would be decontaminated.

After treatment, the waste material (or clean decontaminated material) can be pumped back into the cavity by conducting the borehole mining operation in reverse. Backfilling the cavity in this manner prevents surface subsidence. In a series of phosphate mining tests conducted in St. Johns County, Florida, a

total of 1,700 tons of phosphate ore was extracted from a bed about 20 feet thick at a depth of about 250 feet. The underground cavity had a diameter of 30 to 40 feet, and production rates in excess of 40 tons per hour were achieved. Cavities were backfilled as part of the tests, and subsequent topographical surveys showed negligible subsidence.

### Contact

Dr. George A. Savanick  
U.S. Bureau of Mines  
5629 Minnehaha Ave., South  
Minneapolis, MN 55417

## **INNOVATIVE REMEDIAL TECHNOLOGY INFORMATION REQUEST FORM**

### **INSTRUCTIONS FOR SUBMITTING AN ABSTRACT**

The following is the suggested format for submitting a remedial technology abstract for inclusion in the Synopses of Federal Demonstration Projects for Innovative Hazardous Waste Treatment Technologies. The format has been divided into five sections, each designed to gather specific information for the abstract. These five sections are:

- Technology Description;
- Technology Performance;
- Remediation Costs;
- General Site Information; and
- Contacts.

Although a form has been provided for your convenience, you may submit abstract information without use of this form, or you may attach additional information to this form, as necessary. If possible, this information should be presented in the same order as it appears in this example. It is understood that many abstracts will contain only partial information, as the projects are still being tested; however, please submit as much information as possible, as this will assist others in better understanding the innovative treatment technology.

Abstract information, comments, and questions relating to this project should be directed to:

Daniel M. Powell  
Technology Innovation Office  
U.S. Environmental Protection Agency  
401 M Street, S.W., OS-110  
Washington, D.C. 20460

**INNOVATIVE REMEDIAL TECHNOLOGY  
INFORMATION REQUEST FORM**

**1. TECHNOLOGY DESCRIPTION**

Type of Technology and Exact Technology Name (e.g., Bioremediation: Aerobic Biodegradation of Trichloroethylene):

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Waste Description (e.g., PCB's in sludge):

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Media Contaminated (e.g., groundwater, soil, surface water):

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Targeted Contaminants and Concentrations (e.g., PCB's at 500 ppm):

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Description of Treatment Process:

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Description of Preliminary or Secondary Treatment, If Any:

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Summary of Monitoring Results (e.g., air emissions, waste water discharge):

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Limitations of Technology (e.g., weather, soil type, depth of water table):

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## 2. TECHNOLOGY PERFORMANCE

Overall Attainment of Clean-Up Goals (e.g., residual contamination):

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Summary of Data Used to Evaluate Technology Effectiveness:

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Treatment Capacity (e.g., gallons per day, tons per day):

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Types and Amounts of Residual Wastes (e.g., ash, steam, wastewater):

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Ultimate Disposal Options (e.g., landfilling of ash):

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Malfunctions and Disruptions Encountered:

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Interfering Compounds:

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Description and Length of Future Maintenance and Monitoring Required:

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Additional Comments:

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### 3. REMEDIATION COSTS

Total cost of Remediation Project, Not Including Site Investigations: \_\_\_\_\_

Cost of Remediation Project per Unit of Waste,  
Not Including Site Investigations (e.g., dollars per ton): \_\_\_\_\_

Design Costs: \_\_\_\_\_ Time Required for Design: \_\_\_\_\_

Site Preparation: \_\_\_\_\_

Equipment Costs: \_\_\_\_\_

Start-up and Fixed Costs (e.g., transportation, insurance, shakedown, training): \_\_\_\_\_

Labor Costs (e.g., salaries and living expenses): \_\_\_\_\_

Consumables and Supplies (e.g., chemicals, cement): \_\_\_\_\_

Utilities (e.g., fuel, electricity): \_\_\_\_\_

Effluent Treatment and Disposal: \_\_\_\_\_

Residuals/waste shipping and handling: \_\_\_\_\_

Analytical Services: \_\_\_\_\_

Maintenance and Modification: \_\_\_\_\_

Demobilization: \_\_\_\_\_

Projected Costs of Future Maintenance and Monitoring per Year: \_\_\_\_\_

Estimated Time Required for Operation and Maintenance: \_\_\_\_\_

#### 4. GENERAL SITE INFORMATION

Site Name:

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Site Location:

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Time Period Covered by the Project:

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Scale of Project (i.e., treatability study, bench scale, pilot test, field demonstration or full-scale remediation):

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Site Characterization Data (to the extent that it affects the treatment process):

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Volume of Area Contaminated:

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Facility's Current and Previous Uses:

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#### 5. CONTACTS

Facility Contact:

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Remedial Action Contractor:

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Contractor Contact:

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Other Contacts:

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### **Suggestions**

If you know of additional projects that should be included in this compendium, or if you are often in need of this type of information and don't know how to find it, please make a note on this page. This is a self-addressed mailer -- just add postage, and drop it in the mail.